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PLANTING THE SOUTHERN PINES

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PLANTATION CARE

All southern pine plantations require care from the time the trees are planted until they are cut. They must be protected from a host of enemies--wildfire, sheep and goats, hogs (in the case of longleaf and often of slash), insects, and disease. Heavy mortality the first year or two, as from severe drought, may make replacement planting advisable. Too close spacing or unexpectedly high survival may necessitate precommercial thinning. Commercial thinning is likely to be necessary in any event, and pruning may be wise in some cases.

This chapter describes plantation injuries and their control, replacement planting, pruning, and first thinnings. Fertilization and cultivation are touched on also, though primarily because of their sometimes harmful effects.

PLANTATION INJURIES AND THEIR CONTROL[42]

42/ Cooperators in the Bureau of Entomology and Plant Quarantine, the Bureau of Plant Industry, Soils, and Agricultural Engineering, the former Bureau of Biological Survey (now the Fish and Wildlife Service, Department of the Interior), the Regional Office and National Forests of Region 8 of the U. S. Forest Service, the State forest services, the State agricultural experiment stations, and private industry have contributed to this section a mass of invaluable unpublished data, memoranda, letters, and reports far too great to cite or acknowledge in detail. Specialists in the Bureau of Entomology and Plant Quarantine and the Bureau of Plant Industry, Soils, and Agricultural Engineering have reviewed and approved the text in its present form.

During the period of adaptation right after planting, and again when the crowns close and leaf surface and the requirements for moisture and nutrients reach a maximum, plantations are likely to suffer worse and more varied injuries than natural stands (Baxter by Boyce, 1937; Hartley, 1935; Rudolf, 1937; Rudolf and Gevorkiantz, 1933)(___, ___, ___, ___). Because the great majority of southern pine plantations are still very young, the injuries which have attracted most attention to date have been those characteristic of the earlier of these two critical stages. Ills affecting plantations when the crowns close are beginning to appear, however, and may be expected to increase, and some forms of injury may occur at any stage of plantation development.

Indirect control--that is, correct choice of species, seed source, site, planting method, and silvicultural treatment after planting--may minimize injuries by some insects and diseases (Baxter by Boyce, 1937)(___). Often, however, such injuries result because the correct procedures have not been applied, and other injuries occur regardless of such procedures. In such cases the causes of injury must be controlled directly, if that be possible, and all commercial material salvaged. If the planter fails to act, he risks losing plantations or products that could profitably be saved.

This section gives the available information on the nature and control of injuries of potential as well as of demonstrated importance. It also discusses some trivial injuries, to permit distinguishing them from serious ones on which protection effort should be concentrated. Within each natural group--climate, soil, animals, insects, and diseases-- it deals with injuries as nearly as possible in the order of their appearance after planting. Chemicals or poisons suggested as controls are described in detail on pp. 508 to 535.

Fire

Uncontrolled fire is one of the greatest hazards to planted southern pine, even to longleaf the first year after planting and again just after height growth starts. Every precaution should be taken against wildfire, despite the usefulness of prescribed burning to prepare planting sites, control brown spot (p. 399), and reduce accumulated fuel, and despite the fact that occasional plantations have survived uncontrolled fires with little injury.

Climate

Freezing seldom if ever kills southern pines reproduced naturally anywhere in the southern pine region from parents of local geographic race, except while they are in the cotyledon stage (Chapman, H. H., 1947; Roberts, 1936)(___, ___). In several instances, however, freezing either of the roots of 1-0 seedlings during lifting or planting, or of the soil around the roots within 1 to 2 weeks after planting, has been the apparent cause of serious mortality, particularly of slash pine.

When the roots freeze during lifting or planting, death seems to result from direct injury to the root tissues. When the soil freezes after planting, death seems attributable to excess of water loss over intake, particularly since mortality has been heaviest on bare or nearly bare sites and comparable seedlings frozen in the heel-in nearby have escaped injury. With both types, the symptoms have been the same: a yellowish or grayish bleaching of the foliage, accompanied by drooping and followed by browning and death of the seedlings, all within a very few weeks or even days after the freeze.

Control consists of not lifting and planting during freezing weather, and of stopping planting on advance notice of hard freezes; less directly, of avoiding exposure of planting sites by furrowing, scalping, or burning.

Frost heaving is the lifting up and exposure of part or all of the seedling root system by soil movement accompanying repeated freezing and thawing. It sometimes kills moderate to large percentages of newly planted seedlings and occasionally affects seedlings after one year's growth in plantation. It is intensified by bare, heavy, or poorly drained soil, and by the use of small seedlings (Chapman, A. G., strip mining, 1944; Goodell, 1939; Jones, 1948; McQuilkin, Jour. For., 1946; Minckler and Chapman, 1948; Wilson, 1939)(___, ___, ___, ___, ___, ___). It can be avoided or controlled by maintaining vegetative cover (as by not burning sites before planting), planting in the spring after the worst frosts are over, using large stock, and mulching the trees on bare planting sites with pine needles, grass, or straw.

Heat, although popularly assumed to be a serious hazard to newly planted southern pines, seems to have caused no such damage in the South as it has in the West and North and particularly in the Lake States (Rudolf, 1937; Shirley, 1936)(___, ___). Definite evidence of heat killing of southern pines, even in the first year, and specific symptoms of their injury by heat, have not been reported.

Drought, not only from lack of rain but also from other circumstances which increase water out-go over water-intake, is one of the most widespread and serious hazards to young southern pine plantations (Coulter, 1946; Smith, 1932)(___, ___).

Obviously, many of the circumstances which result in drought-killing (p. 321) are most likely to affect the seedlings during the first growing season after planting (fig. 7, p. 42a). Several of them, like root injury, frozen ground, and soil excessively dry at planting time, have caused visible injury within the first few days after planting and serious mortality within 1 to 2 months.

The symptoms of mild but long-continued or chronic drought are abnormally slow growth, accompanied in the more severe cases by yellowing or fading of the foliage, and the browning and death of some needles. The oldest needles and those only partly developed may show the effects of drought more than those which have recently reached full development. Reduction of vigor by drought intensifies attack by some insects and diseases; severe tip-moth attack on loblolly pine on badly eroded sites, and heavy brown-spot infection of slash pine planted in the hard subsoil of old borrow pits, are characteristic examples. In the most severe or protracted droughts all the foregoing symptoms are intensified and part or all of the seedlings die.

In young seedlings not yet well enough established to resist, the characteristic symptoms of severe but not necessarily prolonged drought are drooping of the foliage (sometimes accompanied by bleaching to yellowish or grayish tint); wilting or shrivelling of newly formed immature needles; failure of buds to open or to continue elongation; browning of all the foliage; and death.

Some of these symptoms are hard to tell from those of other injuries. Occurrence in connection with shortage of rain or soil moisture, or in the presence of non-affected deep-rooted competing plants (lespedeza, for example) often confirms them, however. Such supplementary evidence should be considered when drought injury is suspected.

Defense against drought consists of any and all nursery and planting practices which will enable the seedlings to take in more water through their roots than they lose through their tops. These have been discussed in the sections on planting.

Wind damage, as distinct from glaze (sleet or ice) and snow damage, has not been reported as particularly serious in southern pine plantations. Trees less than 5 feet high usually escape. Taller trees suffer variously from branch breakage, trunk bending, trunk breakage, and windthrow following failure of the roots to hold. Slash pine seems to be the worst sufferer (Cockrell, 1936)(___) (unpublished data), apparently because of its shallow root habit, heavy crown, and perhaps (Koehler, Jour. Forestry, 36: 153, 1938)(___) because of low strength as a result of very rapid growth. Slash pines with trunk cankers of southern fusiform rust seem much more likely to break off at the canker under the impact of strong wind than under the weight of ice or snow. Slash pines planted with U-roots sometimes develop globes of root just under the soil surface, which form "ball and socket joints" when the soil is wet, and let the trees go over in high wind. Experimental evidence and wide observation both show, however, that the danger of windthrow from planting U-roots has been exaggerated.

Young southern pines of all species, but perhaps especially slash pine, straighten up again remarkably when their trunks have been bent within a few feet of the ground by wind, ice, or snow. They do it, however, by forming compression wood on the under side of the bend, to the detriment of practically all products, even pulpwood (Koehler, Jour. Forest. 36: 867, 1938)(___). Such bent and recovered trees, generally recognizable by a slight curvature near the base, should be among the earliest removed in thinnings.

Glaze (ice or sleet) and snow injure or kill planted southern pines by breaking branches, bending or breaking the trunks (fig. 39), or partly or completely overthrowing the trees.

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Figure 39.--Ice damage to planted slash pine near Alexandria, Louisiana. A and B, bending and partial recovery of young trees immediately after and 8 months after storm, respectively. C, top breakage of older tree in storm 3 years before picture was taken. D, permanent deformity resulting from bending of older tree.

Slash pine is most susceptible to glaze injury, and shortleaf least. Smaller trees, including some less than 5 feet high, are especially likely to bend or lean, and trees more than 15 feet high to suffer branch and trunk breakage. Glaze and snow, unlike wind, apparently have little tendency to break rust-infected trees at the canker.

The extent and seriousness of damage vary enormously from locality to locality, year to year , and plantation to plantation (Abel, 1948; Hendrickson and Gibbs, 1949; Koehler, p. 153, 1938; Koehler, p. 867, 1938; McKellar, 1942; Minckler, 1948; Muntz, 1947; Muntz, 1948) (___, ___, ___, ___, ___, ___, ___, ___). Damage is more frequent

toward the north, but sometimes occurs on the Gulf Coast. Glaze seems much more injurious than snow, presumably because accompanying wind intensifies glaze damage while it may shake snow off the crowns. The worst and most frequent damage has been reported from the central and northern parts of Georgia, Alabama, Mississippi, Louisiana, and eastern Texas, where ice storms are common, rather than from more northerly locations where snow is commoner than glaze. In single storms of large extent, damage may be much more severe toward the northern edge of the storm area. Even in severe storms, damage is generally spotty.

Branch breakage, unless extreme, is seldom fatal. Trunk breakage below the living crown is fatal; trunk breakage low down in the live crown, usually so. Breakage high in the crown may leave the tree alive and growing, but fit for short-length, low-grade products only (fig. 39 C). Trees less than 15 feet high, especially if leaning only moderately, often recover remarkably (fig. 39 A and B), but at the cost of forming compression wood. The larger the trees the more likely they are to be permanently deformed. Glaze or snow damage sometimes results in mortality from attacks of *Ips* beetles (p. 390) the following summer.

In localities of high hazard, all reasonable precautions should be taken to minimize possible damage. These include (a) substituting other species for slash pine to the fullest extent feasible, and (b) maintaining full stands of stout-stemmed, long-crowned trees by planting at relatively wide spacing (6 by 7 to 8 by 8 are suggested), removing the shorter-crowned, more slender trees in thinning, and perhaps pruning no trees artificially (Kienholz, 1941; Mulloy by Luther, 1946; Muntz, 1947; Schantz-Hansen, 1939)(___, ___, ___, ___). Excessively wide spacing should be avoided, however, lest glaze damage leave too few well-formed trees for profitable management (Muntz, 1947)(___). Mixing other species with slash as insurance against glaze damage is questionable; in at least one loblolly-slash mixture the bending of slash by glaze increased the injury to the intermingled loblolly (Abel, 1948)(___).

Merchantable trees that are severely injured should be salvaged before warm weather, or at least within the first growing season after injury, but moderately injured trees may often advantageously be left at least until the next scheduled thinning.

Hail storms are relatively infrequent and usually limited in extent. The lighter ones affect planted pines very little, but an occasional heavy fall of large hail stones may severely damage the particular part of a plantation it hits--killing some trees by defoliation followed by *Ips* beetle (p. 390) attack, slowing down growth of the survivors, and causing bark scars that take years to heal (Stone and Smith, 1941)(___).

Soil

Excessive soil moisture tends to reduce the rate of growth of planted southern pines, especially loblolly (Pruitt, 1947)(___), from the first year onward. Occasionally it causes severe mortality, either directly or through the formation of a very shallow root system which fails to supply the tree when protracted dry weather greatly lowers the water table. The injuries are limited to flat sites, visibly wet during most planting seasons, and further distinguished by pitcher plants, sedge, sometimes sphagnum moss, and usually by crawfish burrows. Yellowing of the needles is a common symptom of injury; on trees one to about three years in plantation, hypertrophied lenticels frequently develop just above and just below ground. Injury may be avoided or reduced by substituting slash pine for loblolly or longleaf, by plowing furrows and planting on the furrow slice, or, where economically feasible, by draining the site.

Soil erosion reduces the growth of planted pines, deforms them, or kills them outright. Injury may begin with the first hard rain after planting. It continues in varying degree till erosion has been arrested. It is most likely to occur where erosion-control planting is undertaken. In one case, loblolly plantations on severely eroded soil survived only half as well and produced only one-fifth to one-quarter as much volume in 16 years as others where erosion was slight (Bennett and Fletcher, 1947)(___).

Injury can be reduced to some extent by preserving existing vegetative cover; by not furrowing the planting site or by furrowing on contours only; by using fairly large stock of high physiological quality, and, frequently, by mulching p. 326). Wherever southern pines planted on eroding sites have managed to live and make a little growth each year for 2 to 4 years, they have exhibited a remarkable ability to mulch themselves with their own needle fall, to the great improvement of the site and of their own growth rate thereafter (Gibbs, 1948; Hendrickson, 1945)(___, ___)(unpublished data).

Silting consists of the washing of soil against the stem, foliage, or buds of planted seedlings. The presence of water-deposited soil above the seedling root collar is clear evidence that silting has taken place. It may affect planted longleaf any time before active height growth begins, but is likely to affect other species mostly during the first year after planting, and then only if the seedlings are unusually small or soilwash is extreme.

Setting seedlings $\frac{1}{2}$ inch higher than they grew in the nursery is no longer recommended as a control measure. On land not actively eroding, silting can be minimized by contour furrows, substituting scalped spots for furrows, or planting in unburned or 1-year-old rough.

Low soil fertility appears to be one of the commonest causes of poor growth of planted pines, especially on very sandy soils and on subsoil exposed by erosion, and possibly (Wilde, 1934)(___) on very acid soils. Indirectly it may cause mortality, as by delaying the height growth of longleaf seedlings until brown spot kills them. No practical control is known. For reasons stated elsewhere (p. 412), artificial fertilization is not recommended.

Animals

Hogs, especially those with some razorback ancestry, eat the starchy bark of southern pine seedlings. They prefer longleaf, and, over the southern pine region as a whole, range hogs probably have ruined more longleaf plantations than drought, pocket gophers, leaf-cutting ants, and brown spot combined. To this species hogs are infinitely more destructive than fire. They root out small seedlings entire (fig. 40 A), sometimes at rates of 6 per hog per minute and of 200 to as many as 1,000 per hog per day. They seem to prefer machine-planted to bar-planted seedlings, presumably because they are easier to find and to uproot. They girdle the roots of larger seedlings, and strip the surface lateral roots of larger seedlings and saplings for distances of many feet (fig. 40 B). Although hogs damage slash pine less extensively than longleaf, complete destruction of 900 acres of slash pine within one year after planting has been reported. They occasionally injure loblolly pine. (Hopkins, SFN 50, 1947; Hopkins, 1947; Wahlenberg, 1946; Wakeley, 1935)(___, ___, ___, ___)(Unpublished data).

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Figure 40.--Hog damage to southern pines. A, small longleaf killed by uprooting and stripping of root bark. B, 14-foot slash pine with 16 feet of one lateral root uncovered and stripped of bark. C, site to left of woven wire fence, with same soil, seed source, and fire history as that to right, practically cleared of longleaf seedlings by hogs.

Although it does not completely solve the hog problem, fencing plantations, maintaining the fence carefully, and expelling hogs repeatedly until the trees approach pulpwood size will greatly reduce the damage (Wilkinson, 1948)(___). Where there are many hogs it is foolhardy to plant longleaf without fencing, though mixing another species with longleaf helps somewhat (pp. 18 to 23).

Sheep and goats sometimes kill loblolly, slash, and shortleaf seedlings during the first year after planting, by browsing on them. They may deform a good many and kill a few for a few years thereafter. Sheep retard the height growth of longleaf seedlings, often 25 percent or more, from the time height growth starts until the seedlings are 40 to 48 inches high, by biting off terminal buds, particularly in the

winter and spring. Repeated biting also results in much forking of leaders, and eventually kills some trees. Sheep at the rate of even one per 47 acres have seriously damaged young longleaf stands by biting the buds; sheep at the rate of one every 13 acres, in well-stocked stands of longleaf up to 4 feet high, have injured 86 percent of all seedlings. (Anonymous, Sheep, 1947; Mann, 1947; Smith, 1932; Wahlenberg, 1946; Wakeley, 1935)(___, ___, ___, ___, ___). Goats bite out longleaf buds in much the same manner as sheep.

Both sheep and goats should be excluded from southern pine plantations until the buds and most of the foliage are out of their reach.

Cattle may kill newly planted southern pine seedlings by browsing or trampling them or accidentally pulling them up, kill or deform slightly older ones by browsing, and deform saplings up to 10 feet high by "riding them down" to rub insects off themselves.

Damage may be serious on limited areas of overstocked range, especially where cattle gather near gates, water, feed troughs, or salt, where newly planted pines are the only green food in sight, or where feeding of concentrates has made the animals hungry for roughage (Anonymous, 1926; Barry, 1938; Coulter, 1946; Gibbs, 1948; Gibbs, 1948; Minckler and Chapman, 1948; Wakeley, 1935)(___, ___, ___, ___, ___, ___, ___). Damage is particularly likely in small plantations on farms. Ordinarily, however, unless their presence leads to uncontrolled burning of the range, cattle do negligible damage to planted southern pines (Gibbs, 1947; Gibbs, 1948; Gibbs, 1948; Minckler and Chapman, 1948; Smith, 1932; Wahlenberg, 1935; Wakeley, 1935)(___, ___, ___, ___, ___, ___, ___). Furthermore even light grazing may appreciably reduce fire hazard by reducing the fuel, and may also, especially in the longleaf pine type, offer an attractive source of income from plantations until crown closure greatly reduces the forage (Brasington, Cattle, 1948; Campbell and Cassady, 1947)(___, ___).

Cottontail rabbits (*Sylvilagus floridanus alacer* Bangs in the lower South; presumably *S. floridanus mallurus* Thomas in the Atlantic Coast States) and possibly also swamp rabbits (*S. aquaticus aquaticus* Bachman) cause frequent light and occasional severe injury to loblolly, slash, and shortleaf pine seedlings. They bite off the side branches, buds, upper tops, or entire seedlings, usually the winter they are planted, sometimes the winter following. They bite them off cleanly, usually at an angle of about 45 degrees, in contrast to the irregular cut or break made by cattle, sheep, or goats. They seldom injure the needles, and, unlike hogs, rats, and some insects, do not strip or chafe the bark. Often, though not always, they leave the side branch or top uneaten beside the cut stub. They are much more likely to injure small seedlings than large ones. Damage may not start until cold weather in middle or late December

has killed most late-season green vegetation, and often decreases abruptly during late January or early February. It is most likely to be extensive where rabbits are abundant and have good cover, such as heavy broomsedge (Andropogon) rough or heavy scrub oak or other brush. (Anonymous, 1936; Anthony, 1928; Lay and Taylor, 1943; McCormick, 1948; Minckler, 1944; Smith, 1932; Welch, 1937; Wood, 1936)(__, ___, ___, ___, ___, ___, ___, ___).

The seriousness of rabbit damage depends more on the mortality percent of the injured trees than on the percentages bitten. Recovery from injury during the second winter usually is good. Where the rabbits bite off the tops 1 to 4 inches above the ground during the first winter, or bite only buds or side branches, recovery frequently is good. If the seedlings are large and of high quality , the site is moist, and the weather after planting is favorable, survival may be good even when seedlings are bitten off within $\frac{1}{4}$ inch of the ground, but there may be 10 to 30 percent loss of height growth during the next 5 years, and some forking of main stems at the ground. On dry sites and in dry years, or with small planting stock, biting off of 60 to 100 percent of the seedlings during the first winter has caused enough mortality to ruin plantations. (Wakeley, 1935; Welch, 1937)(___, ___).

Rabbit damage may be reduced: (a) by substituting longleaf pine, which rabbits seldom if ever injure, for more susceptible species; (b) by planting susceptible species after January 15 to February 15; (c) by planting only large seedlings of these species; and, in some instances, (d) by burning over the site before planting. The U. S. Forest Service, in cooperation with the old Bureau of Biological Survey, found a copper carbonate-asphalt emulsion mixture (p. 535) effective in repelling rabbits, and applied it, just before lifting, to seedlings to be planted on sites where rabbit damage seemed likely to be severe.

Eastern pocket gophers (Geomys spp., locally known as "salamanders") apparently vary in importance as plantation pests. In the west Louisiana-east Texas portion of their range (fig. 4, p. 15a), where Geomys breviceps breviceps Baird is the common variety, they have frequently killed most or all trees on areas of half an acre to several acres, and have caused average mortalities of 3 to 20 percent throughout thousands of acres. Damage by other varieties further east has not been recorded in detail, and may be less. Gophers eat the roots of pines they encounter in tunnelling, consuming part or all of those of trees 5 feet or more in height, and often pulling smaller pines bodily into their tunnels and consuming them entirely. They often start killing trees within a few days or hours after planting. Often they kill too few trees, at first, to seem important, but increase in number and extend their depredations inconspicuously for several years until they have reduced the planted stand below the acceptable level. (Anthony, 1928;

Ceremello, gophers, 1938; Crouch, 1933; McPherson, gophers, 1940; Smith, B. F., 1932)(___, ___, ___, ___, ___).

Though seldom seen because they live and feed underground, pocket gophers, when found, are readily distinguished from other injurious rodents. They are stoutly built, with bodies about 7 inches and tails about $3\frac{1}{2}$ inches long. Their ears and eyes are small; their front feet are strong, with long, stout claws well developed for digging; and they have fur-lined pouches opening in the sides of their faces, in which they carry food. The usual signs of their presence are mounds of earth, each a foot or more across, at intervals of a few feet along their irregular burrows; and pale or reddish brown dying or dead trees, often leaning, which are easily pulled up and which reveal only a blunt wooden point where the roots used to be. The burrow system is elaborate, with main and secondary tunnels, and separate storage and sleeping chambers. Most tunnels and chambers are only a few inches below the soil surface. In the southern pine types at least, pocket gophers prefer well-drained soil, coarse sandy soil, or soil with deep rather than shallow sandy surface soil layers above stiffer subsoil. They burrow most actively, and are most easily discovered and controlled, from November until May (Anthony, 1928; Crouch, 1933; McPherson, gophers, 1940)(___, ___, ___).

Control is by strychnine baits, or trapping (pp. 575 to 576). In Louisiana and Texas, at least, it should be applied wherever abundant fresh mounds are found on planting sites, without waiting to find evidence of injured trees. Preferably control should be started a year before planting, and in no case later than the first winter after damage appears. Until the trees are about 8 feet high, annual reinspection, with retreatment wherever gophers have remained active, is essential.

The <u>cotton rat</u> (<u>Sigmodon hispidus hispidus</u> Say and Ord) is the suspected cause of a partial or complete girdling, at or just under the ground line, which weakens or kills planted southern pines up to 2 feet high. The injury, which has been found from Georgia to central Louisiana, is invariably associated with old, heavy rough, known (Lay and Taylor, 1943)(___) to be favorable to cotton rats. The damage is generally unimportant, but is sometimes severe in small areas. It has been noted most frequently on planted and natural longleaf seedlings still in the grass stage. It is easily distinguished from hog damage because the girdles are too narrow to be made by hogs and sometimes show clearly the marks of small rodent teeth; also there is no rooting of the soil , but at most a shallow digging, as by small animals. Burning off the site in advance of planting is suggested as a safeguard where cotton rats are known to be abundant; longleaf plantations in which the injury occurs may be prescribe-burned.

Mice, although an obstacle in the nursery (p. 240) and to direct seeding, appear to be a negligible hazard to planted southern pines (Minckler, "right tree," 1941)(___)(unpublished data).

Insects

Early discovery and prompt action greatly facilitate control of any forest insect. These require frequent, observant travel through the plantations and, usually, advance provision of the equipment and supplies most likely to be needed. For an organization with a planting program of several thousand acres, hand sprayers or highly mobile truck-mounted sprayers sufficient to cover 100 to 200 acres of young plantation in two or three days would seem a minimum safeguard.

Correct diagnosis may be fully as important as prompt discovery of the trouble. Often the planter can identify insects closely enough to choose the type of insecticide to apply, but can follow up the first treatment more effectively if he learns the exact identity of the pest, together with details of its life history. This may require bottling,in ordinary rubbing alcohol, several specimens of the insects and typical examples of their work and mailing them to the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, Washington 25, D. C., or to the State experiment station. The specimens should be labelled with date and place of collection, and accompanied by the fullest possible description of the outbreak.

Insecticides suggested here are described on pp. 508 to 523. Many are extremely poisonous to humans, and their use involves perhaps the greatest single hazard to workmen in the whole process of pine planting. The possible importance of spreaders and stickers (pp. 530 to 532) should not be overlooked. A suitable soap spreader, for example, may double the effectiveness of nicotine (Gwinner, 1946) (___). Although low costs per acre or per tree treated may justify control by airplane dusting or spraying on large planting operations, the total costs will be large. The investment may be wasted through errors in formulating or dispersing spray or in choosing the exact time of application. The planter should therefore consult specialists before undertaking such large-scale control.

Texas leaf-cutting ants (*Atta texana* Buckley, known locally as "town ants") defoliate planted longleaf seedlings, and remove the needles and buds and often the bark of planted slash and possibly of other pines, particularly during the winter months. Within their restricted range (fig. 4), these ants are a serious plantation hazard. Their depredations have necessitated the treatment of thousands of acres of National Forest planting sites in Louisiana and Texas. Failure to treat before or at the start of planting has resulted in injury of more than 50 percent of slash pine seedlings in some plantations, and sometimes in defoliation of all longleaf seedlings on a hundred or more acres within 24 hours after planting. Among longleaf

seedlings defoliated by ants, mortality of 70 percent or more is common, and slash seedlings injured by them almost invariably die. (Ceremello, ants, 1938; Craighead, 1950; Hopkins, 1949; Nicholas, 1940; Smith, B. F., 1932; Snyder, 1936; Snyder, 1937; Welch, 1937) (___, ___, ___, ___, ___, ___, ___, ___).

The tiny mandibles of the ants leave the injured tissues of the seedlings more minutely irregular and frayed than do the teeth of any animals, and do not score, cut, or splinter the wood. The ants do not leave the central portions of the needles as do Colaspis beetles, or conspicuous excreta as do sawfly or Tetralopha larvae. They do not eat the needles, but carry them to underground chambers and grow fungi on them for food. They often leave ½- to 1-inch lengths of needles near the seedlings, and the ants themselves may be found actually defoliating the seedlings. They are more distinctly red than the common mound-building harvester ants, and of several different sizes (castes), the largest with enormous heads and jaws.

The injured seedlings usually are within easy sight of a colony or "town". The colony consists of groups of mounds. Each mound is 8 to 24 inches or more in diameter, crater-like till washed down by rain, colored (frequently red) by subsoil, and containing one or more burrows about half an inch in diameter. The closely spaced mounds of one colony may cover from a hundred square feet to three acres of ground. Lateral burrows and, beyond them, 1-inch-wide cleared trails leading through the grass, often extend a total of 800 feet or more beyond the outermost mound of the colony. Colonies occur at the rate of one per square mile to one every 15 or 20 acres, usually on ridges or well drained slopes (especially south or west slopes) with deep, sandy surface soil. In addition to the conspicuously darker subsoil in the mounds, abnormally thin grass among the mounds and often a dense, rank growth of dog-fennel (Eupatorium capillifolium Small) make all but the newest colonies conspicuous, especially in winter (Smith, M. R., 1939; Walter, Seaton, and Mathewson, 1938)(___, ___)(unpublished data, U. S. Forest Service).

Control is by fumigating the burrows with methyl bromide or carbon disulfide applied in winter (p. 577). Frequent scouting for colonies is necessary, as winged queens can start new ones by flying considerable distances after mating. Treatment must be thorough and checked later, as queens may escape fumigation and rebuild the population before newly planted trees, especially longleaf, are large enough to escape serious injury.

Adult weevils (Hylobius pales Hbst. and Pachylobius picivorus Germ.) attack planted loblolly and slash pine seedlings in the spring. They start with the tender bark near the buds and work downward to strip the bark from the stems and even from the roots to depths of 1 to 5 inches. In north central Louisiana they have caused up to 90 percent mortality in several extensive plantations established after

clear cutting the previous fall to salvage fire-killed pine stands. From this and the known habits of H. pales, it is thought that the stumps and tops left after logging lead to concentrations of the weevils such as may prevent successful planting within two or three years after clear cutting. H. pales has also been found killing small natural longleaf seedlings in Florida. (Craighead, 1950; Sentell, 1949)(___, ___).

The larvae of the Nantucket tip moth (Rhyacionia frustrana Comstock) kill back the tips of planted and natural loblolly and shortleaf pines practically throughout the southern pine region by making longitudinal burrows in the terminal shoots and the ends of the main side branches. Slash pine is attacked nearly as often as loblolly and shortleaf, but (presumably because of its freer pitch flow) is killed back much less severely, and recovers much better. The Nantucket tip moth almost never attacks longleaf pine. (Afanasiev and Fenton, 1947; Baumhofer, 1936; Brown, 1941; DenUyl, 1948; Gibbs, 1948; Gibbs, Forest Farmer, 1948; Hall, 1936; Moore, 1936; Polivka and Alderman, 1937; Wakeley, 1935; Wakeley, tip moth, 1935; Wood, 1936)(___, ___, ___, ___, ___, ___, ___, ___, ___, ___, ___, ___).

Nantucket tip moth clearly is no problem in slash and longleaf pine plantations, but opinions differ widely concerning its seriousness on planted loblolly and shortleaf pines. Injury to young loblolly and shortleaf is conspicuous. It undeniably reduces height growth appreciably through the fifth and sometimes through the tenth year after planting, and causes some trees to crook or fork. Both deformation and loss of growth seem worst on the poorest sites and near or beyond the borders of the southern pine types. The insects seldom kill a tree, and, in general, visible evidence of injury practically disappears before the trees reach minimum pulpwood size. The tip moth therefore seems to be a minor handicap rather than a major obstacle to planting.

The commonest evidence of tip moth injury is the dying or dead twig tips, visible in some stage practically throughout the year. The larval burrows are visible when the twigs are broken open; exit holes in or near the dead buds, often surrounded by pitch, are characteristic. Still living or recently dead twigs usually contain one or several small, light-colored maggot-like larvae apiece, or small, light brown pupae; the pupae wiggle at intervals when breathed on or held in the hand. During the flights of adult moths, empty pupa cases that are split open at the head end can be found in the emergence holes in or near the buds.

The adults are weakly flying moths about 1/8 inch long. Their wings, steeply sloping when at rest, are fringed at the end, and are silvery in color, irregularly crossbarred with brown, matching almost perfectly the sheaths around the bases of loblolly pine needles.

Eggs are laid on needles, buds, and the tender bark of new shoots, and the earliest sign of larval activity is a minute chafing or channelling of needles near the sheath, and of tender bark, as the larvae feed and begin to burrow. A little later, elongating shoots curve, develop pitch blisters where the larvae have entered, and give evidence of dying, and small larvae can be found in short burrows inside.

In the Gulfcoast and adjacent States the moths produce four generations a year, generally at about the time the pines are making new spurts of growth. One generation overwinters as pupae in the twigs; each of the other three completes its life cycle in not more than 8 to 10 weeks. In southeastern Louisiana peak flights usually occur in March, May, July, and September, with pupation following, respectively, in April and May, June, August, and over winter (Wakeley, tip moth, 1935)(___). At Stillwater, Oklahoma, in 1946, peak flights occurred March 22, June 1 to 10, July 10 to 24, and September 5 (Afanasiev and Fenton, 1947)(___). First flights in Tennessee, Kentucky, and southern Illinois begin about the end of February and in southern Ohio about the end of March; in Ohio there are apparently only two generations a year (Hall, 1936)(___).

Control of Nantucket tip moth otherwise than by careful choice of species or species mixture, or by close spacing to improve the form of injured trees, seems generally unnecessary. In exceptional cases it may pay to spray large loblolly or shortleaf plantations on poor sites with DDT, provided care is used to catch the insects during oviposition and egg-hatching. Infested stock intended for isolated and uninfested sites, particularly beyond the borders of the southern pine types, should be dipped in a miscible oil emulsion, alone or with nicotine, or sprayed with DDT at the nursery, but this precaution is useless in planting on sites on which the tip moth is already present.

Rhyacionia rigidana Fernald, a shoot moth somewhat larger than the Nantucket tip moth and capable of killing back slash pine conspicuously, was identified on slash pine in Lanier County, Georgia, in June and again in September, 1929 (unpublished data). Craighead and also Doane and co-authors mention it as attacking loblolly and Virginia scrub pine in the Atlantic States, and Craighead says it has either 1 or 2 generations a year (Craighead, 1950; Doane, VanDyke, Chamberlin, and Burke, 1936)(___, ___). The apparent lack of any later reports indicates that it is an unimportant pest in southern pine plantations.

Sawfly larvae partly or completely defoliate southern pines, planted or natural, from the age of one year onward. Potentially at least, sawflies are a considerable hazard to southern pine plantations because of their demonstrated ability to kill some trees and to reduce appreciably the growth of entire stands over large acreages (Beal, 1942; Erambert, 1940; Kowal, 1948; Schaffner, 1943)(___, ___, ___, ___).

The commonest species seems to be the red-headed pine (Leconte's) sawfly (Neodiprion lecontei Fitch), which attacks all the principal southern pines, but at least two other species attack loblolly, and at least three others attack shortleaf. (Craighead, 1950; Kowal, 1948; Middleton, 1927; Polivka and Alderman, 1937; Schaffner, 1943; Wakeley, 1935)(___, ___, ___, ___, ___, ___).

Sawfly larvae eat needles down from the tip instead of cutting them off at the base as do leafcutting ants. Whereas ants confine their attacks to small seedlings and to the winter months, sawfly larvae feed on pines of all sizes, and usually in the warmer months, and in many localities beyond the range of the ants. Sawfly larvae frequently leave the needles only partly consumed, but, except when the larvae are very young, leave the basal portion, not a central core as Colaspis beetles do. The ground under sawfly-injured trees usually is liberally sprinkled with excreta, but, in contrast with Tetralopha, the larvae leave no webs full of excreta on the trees.

Sawfly larvae look like the caterpillars of moths or butterflies, but have only 8 (occasionally only 6) pairs of fleshy, jointless prolegs under the rear three-quarters of their bodies, whereas most moth or butterfly caterpillars have 10 pairs. Depending on their age and species, sawfly larvae vary from 1/8 inch to nearly 1 inch long. They are hairless, and usually striped or spotted; the larvae of the red-headed pine sawfly are variously spotted, and have orange, mahogany-red, dark brown, or nearly black heads (fig. 23 D, p. 242). They feed in groups; often two or three larvae work opposite each other on different sides of a needle, eating it off completely as they back downward from the tip. When jarred or startled, they rear back suddenly and remain motionless for a moment.

Sawfly larvae are easily controlled by spraying with DDT or arsenate of lead, but attempts to kill all sawfly larvae appearing in plantations are not recommended. Concentrations on single or scattered trees, or light outbreaks covering a fraction of an acre or even several acres, can do little harm in themselves. Close watch should be kept for large outbreaks, however, and places known to have been infested once should be watched for larger and heavier reinfestations. Any outbreak large and heavy enough to cause economically serious losses, or threatening to progress to dangerous size, should be controlled promptly by spraying. If the sawfly population is indeed building up, each successive brood will cover more area, and be harder to control. If the current brood is discovered just as it is about to stop feeding and begin to pupate, one or two days' delay may make spraying useless.

Pine webworms are the larvae of a stout, soft-bodied moth, Tetralopha robustella Zeller. The 3/4-inch long, brown-striped caterpillars often feed singly or in small numbers on the needles of southern pines, especially within the first two years after planting. The caterpillars have been reported in early summer, but

more often in the late summer, fall, and mid-winter, usually on the most recent foliage (that nearest the terminal bud) of slash and longleaf. Each caterpillar lives in a mass (sometimes a distinct tube) of excreta and webbing. These tubes are conspicuous, and make the injury look worse than it really is. The larvae are not heavy feeders, and rarely do much harm unless they are unusually abundant or the seedlings are very small and weak when attacked. They can be controlled with DDT or arsenate of lead.

The adults of Colaspis pini Barber, brownish beetles about 3/16-inch long, have attacked young planted pines of the four principal species at intervals since 1924, and also young and mature natural stands, at widely separated points from South Carolina and Florida to southeastern Louisiana. The largest and most frequent outbreaks--10 to 500 acres--have been reported from southeastern Louisiana and the adjacent portion of Mississippi. The adults emerge in June, and feed for considerable periods, usually on the outer ends of the current year's needles. First the outermost and then the remaining portions of the injured needles turn reddish brown. From a little distance an infested plantation looks as though a fire had run through it. Close examination shows that the beetles have eaten the edges of the needles but left the central portions; sawflies, by contrast, usually eat the entire needle as they go. Damage sometimes is mainly to the upper part of the crown. The visible external traces often disappear within a few months. Some decrease in growth has been suspected, but little or no mortality has followed attacks. The beetles are easily controlled with lead arsenate and presumably with DDT, but spraying hardly seems justified unless the outbreaks recur or increase the second year. (Craighead, 1950; Snyder, 1940; Wakeley, 1935)(___, ___, ___).

White-fringed beetles, whose economic importance necessitates rigorous inspections and quarantines affecting nursery stock (p.243), appear to feed little, if any, upon pines. DDT has been found extremely effective against this insect, and, should attacks on pines develop, the latest specifications for control should be requested from the U. S. Bureau of Entomology and Plant Quarantine, Washington 25, D. C., or its local offices.

Bark beetles, especially the southern pine beetle (Dendroctonus frontalis Zimm.) and various species of Ips, become an increasing threat as planted southern pines approach maturity. Adults and larvae of these beetles cut egg-chambers and galleries, respectively, through the cambium layer, removing part of the outermost wood and the inner bark. The beetles are most active in warm weather, and in fire-weakened, drought-weakened, and otherwise injured trees. They seem more of a hazard in the Piedmont and in the Appalachian foothills than in the Coastal Plain. Dendroctonus occurs in serious epidemics at considerable intervals, disappearing almost completely between times; during epidemics it kills vigorous mature trees. It can be

controlled by utilizing the trees and burning the infested bark of brood trees. Recent investigations have shown that broods in trees can be controlled by spraying the trunks with an oil solution of benzene hexachloride. *Ips* is a moderate hazard every year, and sometimes becomes seriously epidemic in drought years. It attacks mostly weakened or injured individual trees or groups, but sometimes kills vigorous young saplings. (Craighead, 1950; Craighead and St. George, 1928; Doane, VanDyke, Chamberlin, and Burke, 1936; Graham, 1929; Stone and Smith, 1941)(___, ___, ___, ___, ___).

Plantations damaged by fire, ice, hail, or lightning should be watched closely for *Ips*, especially from about March onward until cold weather the following winter. Signs of *Ips* are fading and browning of the tops, small pitch tubes on the trunks, and characteristic galleries under the bark, and, ultimately, small emergence holes through the outer bark. (*Ips* larvae are small, not to be mistaken for the larger "sawyers" or flat-headed borers that infest dead trees.) *Ips*-infested trees of merchantable size should be cut and salvaged; if they are cut and utilized while the larvae are still in them (that is, before emergence holes appear), enough of the insects may be killed to stop their spread. There seems little use in cutting infested trees below merchantable size.

From March till late fall, and occasionally over a mild winter in the lower South, tremendous populations of *Ips* build up in fresh tops and other residue of logging, including thinning for pulpwood. The beetles may then attack weakened standing trees nearby, and even thrifty trees of small size. Since commercial logging and thinning cannot be confined to cold weather, the beetles are an ever-present threat to the stands left. The threat, however, is usually negligible so long as the operation is continuous over considerable areas and fresh supplies of tops become available week by week during warm weather. A small, isolated cutting in warm weather often leads to *Ips* attack on living trees in and around the cutting. For this reason, isolated thinnings on experimental plots or in small farm plantings should be made in midwinter.

Insects of apparently minor importance. Several insects of minor importance have been reported in southern pine plantations or in young natural stands under conditions resembling those in plantations. Artificial control is not recommended unless local evidence shows appreciable injury and aggressive spread. They include:

Grasshoppers, which have been observed partly defoliating pine seedlings the first year after planting.

Scale insects, especially *Toumeyella parvicorne* Ckll. on young leaders, twigs, and needles, and *Chionaspis (Phenocaspis) pinifoliae* Fitch on the needles, reported in each of several southern States. (Although these seem to do little harm when infestation occurs after

planting, active Toumeyella infestation on nursery stock late in the nursery growing season usually results in heavy mortality after planting.)

Aphids, on planted slash and loblolly pines up to 5 years old.

Larvae of the moth Dioryctria amatella Hulst. (primarily a cone borer), which have been found burrowing in the elongating leaders of longleaf pine in Louisiana and Mississippi in the spring and in the late summer (Craighead, 1950)(___).

A needle miner of the genus Recurvaria, which has occasionally attacked young longleaf pine in Louisiana and Texas in April, August, and November.

The Zimmerman pine moth, Dioryctria (Pinipestis) Zimmermani Grote, a bark borer the larvae of which have attacked the trunks of planted shortleaf and other pines in Ohio and elsewhere (Craighead, 1950; Polivka and Alderman, 1937)(___, ___).

When the seriousness of insect attack on a plantation is in doubt, identification of one of these minor insects as the cause of injury may save unnecessary expenditures for control.

Diseases

Southern fusiform rust is the most serious disease so far encountered in the southern pine planting program. It is caused by Cronartium fusiforme Hedgcock and Hunt. This fungus infects slash and loblolly pines in the nursery and from the first spring after planting until they are at least 50 to 60 feet high, forming cankers on the branches and trunks. It also infects longleaf in the nursery and doubtless infects some planted longleaf before it starts height growth. Infection continues until after longleaf reaches merchantable size, though seldom as extensively as on slash and loblolly. Fusiform rust is rare on shortleaf pine (footnote 35, p. 253). (Hedgcock and Siggers, 1949; Siggers, 1946; Siggers and Lindgren, 1947)(___, ___, ___).

Seedlings infected in the nursery seldom survive planting (p. 252 and fig. 24 C). Infection incurred after planting kills many trees (fig. 41 C) and reduces the value of products from the survivors (fig. 41 F, G, and H). The rate of infection is high within most of a wide territory (fig. 4) and in many restricted localities outside it, and has shown an alarming tendency to increase (fig. 41 B and C) in places where the hazard originally seemed slight.

The South's two favorite planting species, slash and loblolly, suffer most from the rust, and mortality is particularly heavy in slash. Thirty percent mortality, with 60 to 80 percent trunk infection among the surviving trees, is not rare in slash pine plantations still below minimum pulpwood size (fig. 41 A and C). Infection of both branches and trunks (fig. 41 D) continues as the trees grow. Infection is progressive; branch cankers, relatively harmless in themselves (fig. 41 E), grow into and dangerously involve the trunk (fig. 41 F), and trunk cankers may increase enormously in size (fig. 41 B, F, and G). In contrast to brown-spot and other needle infections, which are shed or burned with the needles, rust infections in the main stems can be eradicated only by cutting the trees. Except in the nursery, the rust is almost wholly unpreventable and uncontrollable by direct means. (Gibbs, 1948; Gibbs, 1948; Hartley, 1938; Siggers, 1946; Siggers and Lindgren, 1947)(___, ___, ___, ___, ___) 43/.

43/ Its sweet-potato-shaped (fig. 41 E) or irregular cankers (on trunks, frequently with flattened or depressed (fig. 41 B and F), dead, often pitch-covered centers), and the tendency of its cankers to grow down along the branch into the trunk and to enlarge upon the trunk, usually distinguish fusiform rust from a much less serious rust caused by Cronartium cerebrum Hedgcock and Long. C. cerebrum is common on shortleaf, Virginia, sand, and spruce pines, and occurs on loblolly, and rarely on slash. Its cankers are always swollen globose galls, with distinct "collars" of bark both above and below the swelling, and are almost invariably confined to the region of original infection. C. cerebrum may kill or stunt some seedlings or small trees, but on large trees it commonly lives for years with little detriment to the pine. Its life history is closely similar to that of C. fusiforme. (Hedgcock and Siggers, 1949)(___).

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Figure 41.--Various stages of southern fusiform-rust infection and resulting damage on planted slash (A through E), planted and natural loblolly (F and G), and natural longleaf (H) pines, in various localities from Sumter County, Alabama, and Harrison County, Mississippi, to Beauregard (B) and Rapides (C) Parishes, Louisiana. (Photos 41E and 41G are by the Bureau of Plant Industry, Soils, and Agricultural Engineering.)

Cronartium fusiforme 44/ requires two different hosts, pine and

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44/ Save as specifically noted, the paragraphs on the rust caused by this fungus are based largely on unpublished memoranda and reports by Dr. Paul V. Siggers, U. S. Bureau of Plant Industry, Soils, and Agricultural Engineering.

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oak, to complete its life cycle. Within a single growing season, infection passes from pine to oak, from oak to oak, and from oak back to pine again. On the individual pine, infection frequently extends downward along the branch into the trunk, but it cannot spread from one pine tree to another (Hedgcock and Siggers, 1949; Siggers, 1946; Siggers, 1947; Siggers and Lindgren, 1947)(___, ___, ___, ___).

The round of infection from pine to oak to pine occurs only in the spring--in the Gulf States, usually from about mid-March to mid-June. It begins with a tremendous production of orange aeciospores on branch and stem cankers on the pines, in March and April, rarely in late February. These infect the new foliage on various oaks. Oaks differ greatly in susceptibility. The red or black oaks, including southern red oak, bluejack, and blackjack growing on upland sites, are important alternate hosts. Water, willow, and laurel oaks, which grow along small streams throughout many of the pine types, are extremely susceptible and are a very important source of infection of the pines. The white oaks as a group, including post oaks, are the least important.

Infections on the oak result in multitudes of yellowish spots on the lower side of the leaves. Within these spots are produced urediospores, which are capable of reinfecting oak leaves and forming new spots. They may very greatly increase the total number of spots on the oaks in a given year, thereby contributing indirectly to heavy infection of the pines. They do not, however, infect pines directly.

After a minimum of 7 to 10 days, telia are produced in tremendous quantities from around the bases of uredial fruiting bodies on the under sides of the oak leaves--both in the spots originating from urediospores and in those originating from aeciospores blown in from the pines. These telia are brown, bristle-like columns, sometimes 1/10-inch long, projecting downward from the leaf spots (fig. 24 A). They can be found in great numbers, often dozens and sometimes hundreds to a leaf, in April, May, and June.

The telia produce innumerable very small, thin-walled spores. These spores, the sporidia, become detached and are blown by the wind back to the pines, which they infect. Infection of pine can take place through the epidermis of newly germinated seedlings; this is the manner in which seedlings commonly become infected in the nursery. Larger pines may become infected through the epidermis of new shoots before the bark is formed, but most infection of planted pines is thought to pass into the twigs or stems through the needles. Infection takes place most easily in new needle tissue. Since new needle tissue is present both in needles just developing from elongating buds, and in needles of the previous year which are increasing in length at the base, infection occurs on stem wood of

both the current and the previous year. In the Gulf States, the peak of pine infection is from about mid-April to mid-May, but infection may continue to some extent until at least the middle of June.

Infection of pines depends on the production of telia on the oaks and of sporidia on the telia, and on the dissemination of sporidia to and their germination on the pines. Once telia have formed on the oaks, abundant infection may take place on the pines whenever the temperature remains between 60° and 80° F. and the relative humidity remains at or very near 100 percent for at least 18 hours (Siggers, 1947; Siggers, 1949)(___, ___).

Susceptible pines are likely to suffer heavy (20 to 40 percent) or very heavy infection wherever there is a combination of: (1) abundant oaks, especially of the more susceptible species, within 1 or 2 miles; (2) a March to June climate marked by 18-hour or longer periods of 60° to 80° F. temperature and essentially saturated atmosphere; and (3) even a light initial production of aeciospores, on natural or planted pines, to infect the oaks. The second element in this combination is sometimes difficult to recognize in advance of planting, but frequently can be surmised or learned from weather records, and may be assumed if pines in the vicinity are heavily infected with rust, particularly if infection clearly has taken place in several different years.

Where the foregoing combination exists, or is likely to arise within 10 to 15 years after planting (as from gradual building up of oak thickets or of light infection in new pine plantations), the safest course is to plant the less easily killed loblolly instead of slash, or, better, to plant longleaf or shortleaf. If 10 percent or more of young longleaf pines near the planting site are infected with fusiform rust, it is better to plant longleaf than either slash or loblolly, because slash and loblolly are likely to be very severely damaged under conditions permitting such infection of longleaf. Eradicating the oaks to control fusiform rust in southern pine plantations, as currants and gooseberries are eradicated to control the closely related white pine blister rust, is impracticable.

Where the combination favorable to heavy infection already exists, the exact degree to which the pines become infected depends mainly on the abundance of new needle tissue during the production of sporidia on the oaks. Anything that causes the pines to elongate their buds and expose new needles (or to resume elongation of the previous year's needles) at an earlier date than usual is almost

certain to increase infection. 45/

45/ Mere rapidity of growth after elongation has started has no such effect; see the faster height growth and lower infection of the Louisiana and Texas as compared with the Georgia stock in table 2, and consider the faster growth of 5-year-old trees as compared with that of the 1- and 2-year-old trees mentioned in the next paragraph.

Young pines elongate their buds considerably earlier than older ones--weeks earlier in some cases. In any given place and year, therefore, infection usually is most prevalent in 1- and 2-year-old plantations and progressively lighter in older ones. Geographic source of seed may affect date of bud elongation; Siggers has shown that the heavily infected trees of Georgia stock described in table 2 exposed new needle tissue earlier in the spring than the lightly infected trees of Louisiana stock.

Current or past cultivation or fertilization of the planting site similarly causes growth to start earlier in the spring and results in greatly increased rust infection (p. 412). Planted slash or loblolly pines should not be cultivated or fertilized in any locality in which southern fusiform-rust infection is appreciable.

Both earlier elongation of the buds and increased rust infection on the new growth of the main stems result from fire which partly defoliates but does not kill young planted slash pine. Similar increased infection (Muntz, 1948)(___) has occurred on planted loblolly pine partly defoliated by fire. Prescribed burning seems unlikely to increase infection on trees more than 10 years old, however, and may be used for fuel reduction in stands of that age, without apprehension as to rust (Siggers and Lindgren, 1947) (___).

Fusiform-rust infection within two or three years after planting is not only heavier, but also more dangerous, especially to slash pine, than is later infection. Cankers affecting the main stem while it is still small are particularly likely to girdle it quickly and kill the tree. Trunk cankers on small trees are necessarily low down, where they will do the most harm even if the tree survives (fig. 41 A). Lastly, the side branches of very young trees are short enough so that infections even at their tips may run into the trunks.

Fusiform-rust cankers may be harmless as long as they remain confined to the branches. There is no evidence that such cankers reduce the growth of southern pines any more than, if as much as, branch cankers of white pine blister rust reduce the growth of western

white pine (Buchanan, 1944)(___). Branch cankers, however, especially on vigorous branches, grow toward the trunk at an average rate of about 3 and a maximum rate of 9 or more inches per year. Therefore any branch canker arising within a foot or 18 inches of the trunk (fig. 41 E) is likely to invade it, and even a canker originating 2 feet out may do so. Planting at somewhat closer than 6- by 6-foot spacing counteracts high fusiform-rust hazard not only by offsetting mortality and permitting wide choice of trees to leave in thinning (Cline and MacAloney, 1935)(___), but also by shading many lower branches to death before the cankers on them grow into the trunks (Mann and Scarbrough, 1948; Muntz, note 53, 1948; Siggers and Lindgren, 1947)(___, ___, ___). Where percentage of trunk infection is low, ultimate losses from rust may be considerably reduced (particularly in young plantations spaced more widely than 6 by 6 feet) by pruning off (p. 422) side branches cankered within 12 to 18 or even 24 inches of the trunk. In extreme cases it may pay to prune in this way every year for several years, or in the winter following each spring highly favorable to infection (Siggers, 1948)(___). Such pruning is useless, however, on trees already infected in the trunk.

Even in plantations with a high percentage of trunk infection, judicious thinning (p. 419) will often salvage much merchantable wood.

Brown spot needle blight, caused by Scirrhia acicola (Dearn.) Siggers, is a serious obstacle to planting as well as to natural reproduction of longleaf pine. It injures or kills part or all of the needles on trees up to 2 and occasionally up to 8 feet high. It occurs also on all the other principal and most of the minor southern pines, on southern pine hybrids, and on several exotics, from the Gulf States at least to Arkansas, Ohio, and North Carolina, and possibly to the northern-most ranges of loblolly and shortleaf pine (Siggers, 1944)(___). Infection is not, however, equally severe in all places (fig. 4), and the disease is rarely of economic importance except on longleaf.

Directly or indirectly, brown spot is the principal cause of the continuing mortality of longleaf during the second through the tenth to twentieth year after planting (fig. 7, p. 42a); where uncontrolled, it has ruined large plantations. As has been shown both by records of infection classes determined at the start of the fourth growing season and by numerous experimental sprayings with fungicides, it greatly reduces the growth of seedlings which survive infection (figs. 42, 43, and 46), often to one-third and in extreme cases to one-twentieth of that of uninfected or lightly infected trees. Such delays in early height growth prolong the period of hazard from drought, vegetative competition, hogs, and the numerous other enemies of young longleaf, including brown spot itself. The disease, however, need be no such calamity as hog damage or several other ills. Ordinarily it does little harm to longleaf pines more than 18 inches high, and those above 30 inches high are safe from all but the worst epidemics. Serious outbreaks in stands averaging less than 18 inches

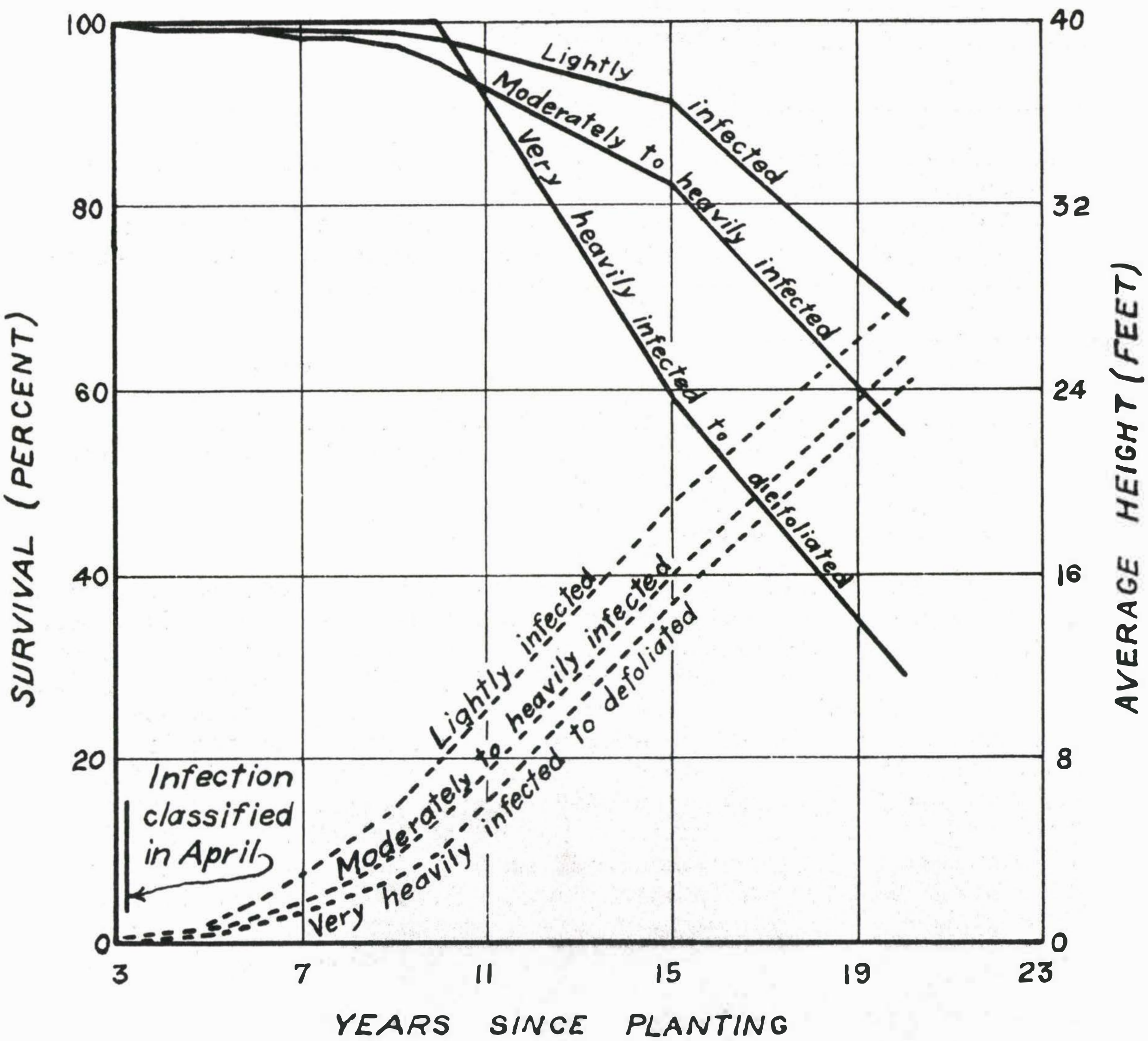

Figure 42.--Development of planted longleaf pine, unsprayed and unburned, at Bogalusa, Louisiana, by brown spot infection classes determined at start of fourth growing season after planting. (Solid lines, survival percent based on trees alive when classified; dashed lines, average heights of survivors.)

high can be recognized before they get out of hand, can usually be prevented or controlled at reasonable cost, and have been controlled on a large scale for many years. (Chapman, 1926, Siggers, 1932; Siggers, 1934; Siggers, 1944; Siggers, 1945; Wahlenberg, 1946; Wakeley, 1935; Wakeley and Muntz, 1947; Wilkinson, 1948)(___, ___, ___, ___, ___, ___, ___, ___, ___)(unpublished data).

Figure 42.--Development of planted longleaf pine, unsprayed and unburned, at Bogalusa, Louisiana, by brown spot infection classes determined at start of fourth growing season after planting. (Solid lines, survival percent based on trees alive when classified; dashed lines, average heights of survivors).

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Figure 43.--Longleaf pine at Bogalusa, Louisiana, mostly stunted or killed by 15 years' uncontrolled brown-spot infection (row at left), and saved by semi-annual spraying the first 2 years after planting (row at right).

Brown-spot infections of three different appearances are common: (1) ordinary external spots; (2) external "bar spots;" and (3) internal killing of the needle tissue without distinct spots, but with yellowish flecks on the green part of the needle, followed quickly by yellowing and often finally by reddening or browning of the whole needle. The ordinary spots are straw yellow at first, later turning light brown, often with chestnut-brown borders when fruiting bodies form, or, in the fall, with dark purplish borders. Maximum length of a single spot is about 1/8 inch; it may or may not girdle the needle. The fruiting bodies appear as small, dark specks on the surface of the spot. Separate spots frequently run together, and eventually the needle tissue beyond and between groups of spots dies. Uninfected tissue shrinks more than do the spots, giving the dead needle a faintly mottled, embossed appearance. Bar spots begin as plain, amber-yellow bands encircling about 1/8 inch of the needle. Later, a circular, brownish spot about the size of a pinhead appears in the yellow band, usually remaining localized on one side of the needle, though sometimes encircling it. Both forms of spots have distinctly defined margins, a feature which distinguishes them from those caused by several other diseases. These two forms may appear at any season of the year. The interior infection that flecks, yellows, and kills the entire needle occurs in cool weather and usually is at a maximum from the first of March till the middle of April.

The fungus causing brown spot passes its life cycle entirely upon pines. Infection passes directly from one pine to another by ascospores or conidia.

Ascospores are produced in the winter and spring, usually if not always after the death of most of the infected needle (Siggers, 1944)(___). They are not known to occur at other seasons, although observed patterns of infection suggest that they may do so. Ascospores are light, dry, and wind-borne. They characteristically cause light, scattered infections, sometimes at very great distances. They sometimes cause isolated spots on the foliage of tall trees, although by far the greatest part of all infection occurs within 18 to 30 inches of the ground. Ascospores are thought to be the principal means by which brown-spot infection invades nursery beds, plantations established with uninfected stock, and planted and natural stands freed of brown spot by burning.

Conidia may be produced by the fungus on diseased portions of still living needles at practically any time of year when two or more days of rain coincide with temperatures between 45° and 95° F. Apparently they may develop within 14 to 20 days of the initial infection of the needle. The conidia are produced in sticky masses. They are not wind-borne, except perhaps occasionally in water droplets, but are washed apart and splashed for short distances by rain. They carry infection to seedlings a few inches away (as in nursery beds) and possibly 2 or 3 feet (as to nursery stock planted close to occasional infected natural seedlings already on the planting site). They may be spread to considerable distances by animals or man, though this has not been proved. Principally, however, conidia intensify infection on seedlings already lightly infected. Under ordinary weather conditions and in the absence of direct control, infection in longleaf pine plantations established with uninfected or lightly infected stock may rise to averages of 14 to 25 percent (p.408) within 6 months to a year after planting, of 30 to 77 percent within two years, and of 57 to 99 percent within three or four years (Howard Lamb, unpublished data, U. S. Bureau of Plant Industry, Soils, and Agricultural Engineering). There is one record of a similarly rapid increase to 40 percent in the third year with loblolly pine, a species not ordinarily badly affected by brown spot (Toole, 1939)(___).

Dangerous brown-spot infection of planted longleaf pine can usually be delayed and sometimes prevented altogether by spraying the stock in the nursery (pp. 255 and 265). Any appreciable number of infected natural seedlings present may, however, necessitate burning over the site before planting (pp. 323 to 324) to get the full benefit of the nursery treatments.

Although spraying twice a year for 2 years (p. 396) may give feasible control of brown spot where infection builds up only moderately fast, spraying plantations often enough to control brown spot where infection rapidly becomes severe is too expensive for commercial use. Most incipient brown-spot epidemics on planted longleaf can, however, be controlled safely, effectively, and economically by prescribed burning (Bickford and Bruce, 1948; Bickford and Curry,

1943; Bruce, 1947; Byram, 1948; Byram and Lindenmuth, 1948; Chapman, 1926; Chapman, "effects", 1936; Chapman, 1947; Demmon, 1935; Heyward, 1937; Heyward, 1938; Heyward and Barnette, 1934; Lindenmuth and Byram, 1948; Morriss and Mills, 1948; Siggers, 1932; Siggers, 1934; Siggers, 1944; Siggers, 1945; Simerly, 1936; Squires, 1947; Wahlenberg, 1946; Wakeley and Muntz, 1947; Wilkinson, 1948)(___, ___). The references just cited give details of technique, results, and costs for prescribed burning to control brown spot. Costs usually include the loss of some seedlings from the fire itself, but in correctly timed and executed burns such losses usually are negligible in comparison with benefits.

The following are general guides in burning longleaf and mixed longleaf-slash plantations to control brown spot:

1. Prescribed burning ordinarily should be done in January or February unless local circumstances indicate that slightly earlier or later burning is preferable.

2. Burning should not be done at any fixed interval after planting--in the third winter, for example--but when and only when made necessary by the development of brown spot and rendered safe by the height and condition of the seedlings. An average foliage infection of or exceeding 35 percent--meaning that 35 percent of all the needle tissue produced during the current year is included in brown-spot lesions, dead needle-tips, and needles killed outright by the fungus (p. 408)--in December or late November indicates the need for burning the following January or February. Infection percentages of 12 to 20 percent in one winter often lead to more than 35 percent infection a year later, and give advance warning of the possible or probable need for firebreaks, allotments of funds for burning, and the like.

3. Longleaf seedlings $\frac{1}{2}$ foot to 4, 5, and even 6 feet high are much less able to resist fire than are seedlings which have not yet begun active height growth. This is particularly true of seedlings weakened by repeated heavy brown-spot infection (p. 410), and especially if they have large percentages of brown-spot-killed foliage at the time of the fire. The time to control brown spot by burning therefore is before any large percentage of the planted longleaf seedlings have begun height growth, and especially before the seedlings which have started growth have become weakened by the disease. Longleaf seedlings which have developed conspicuously tapering stems as a result of repeated brown-spot infection (fig. 45) are likely to be killed by even light fires.

4. There is considerable evidence that, with proper care, longleaf seedlings one growing season in plantation may be prescribe-burned if necessary. Certainly, if longleaf plantations have become seriously infected during the second year after planting, it

is far better to prescribe-burn them at the end of the second year than to wait till the end of the third. Postponing the fire one year means greater mortality from the brown spot, greater delay in height growth of the survivors, and more seedlings killed by the fire because they have started height growth or have been weakened by the disease.

5. Prescribed burns should be thorough enough to reach practically all infected seedlings, and hot enough to brown, though preferably not hot enough to consume, all needles as high up as infection extends on the seedlings. Light, patchy burns are ineffective in controlling brown spot.

6. The larger the area that is burned, the slower brown spot reinvades, and the greater the benefits. Burns of 500 to 1,000 acres are none too large for most economical treatment and best effect. Smaller burns may be beneficial under certain circumstances, however, and it may sometimes be essential to prescribe-burn isolated longleaf plantations of an acre or less.

7. Under a variety of local circumstances, and chiefly where vigorous height growth is long delayed, a second or even a third prescribed burn may be necessary within 2 to 5 years to maintain the benefits of the first burn.

8. Slash-longleaf mixtures present a difficult problem in prescribed burning for brown-spot control With care, however, slash pine can be prescribe-burned when 10, 6, or, in extreme cases, only 2 feet tall (Lemon, 1946; Siggers, 1945; Simerly, 1936; Squires, 1947)(___, ___, ___, ___). This at least leaves the way open for useful prescribed burning of mixed slash-longleaf plantations in which the longleaf needs, and can stand, burning in the third, fourth, or fifth winter after planting.

Needle cast, caused by *Hypoderma lethale* Dearn., attacks planted southern pines of all ages practically throughout their range, but has been reported most frequently from the Gulf States and on loblolly pine. Infection takes place directly from pine to pine, apparently in midsummer on needles of the current year. The fungus attacks the needle tips first and progresses downward, turning the tissues light green or gray-green, and finally brown, until by the following spring at least 60 percent of the length of the needle is dead, or the whole needle has fallen. The disease does not cause definite spots as does the brown-spot organism, nor is the margin of infection sharply defined. *Hypoderma* produces black fruiting bodies on discolored portions of needles still green at the base. Heavy infection presumably reduces growth, but is not known to kill trees. Plantation spraying is not recommended, as outbreaks usually clear up spontaneously. (Boyce, 1948; Davis, Wright, and Hartley, 1942)(___, ___).

Needle rusts of the genus Coleosporium infect planted southern pines,producing orange aeciospores in small but conspicuous white or pinkish fruiting bodies arising from small spots on the needles in the spring. They pass the rest of their life cycle on various herbaceous alternate hosts, usually composites. Their appearance on the pines is somewhat striking in years of abundant spore production, but so far as is known their effect is negligible, and no control is necessary or has been attempted. (Boyce, 1948; Hepting, 1933; Polivka and Alderman, 1937)(___, ___, ___).

Littleleaf, first reported in 1934-1935, is a disease of shortleaf and to a lesser extent of loblolly pine. It occurs largely though not wholly in the Piedmont (fig. 4) and here it is the most important tree disease; it kills millions of dollars worth of pines annually, and constitutes one of the most serious silvicultural and economic problems in the southern pine region. (Malsberger, 1948; Southeastern Forest Experiment Station, 1948)(___, ___)

Littleleaf presents an appearance of nutritional deficiency or of premature senility. Its most outstanding characteristic is a progressive annual shortening of twig growth, which makes the foliage look sparse. This is accompanied by abnormally short needles, yellowish rather than normally green needles, a falling off of diameter growth, dying of the crown from below upward, certain root abnormalities, and ultimately, death of the tree, sometimes in about 7 years, sometimes in much less. Neither cause nor control is known. On sites on which it occurs, littleleaf affects trees over 20 years and more than 3 inches in diameter, regardless of vigor, crown-class, or position in the stand. (Hepting, Buchanan, and Jackson, 1945; Jackson, 1945; Roth, Toole, and Hepting, 1948)(___, ___, ___).

Littleaf has not been reported in plantations, in all probability because few or no plantations in the littleleaf territory are old enough to be affected. The disease is so serious, however, that extreme caution is advised in planting pure shortleaf where there is any evidence of littleleaf. Planting loblolly may also be risky, but seems preferable to planting shortleaf. Slash and longleaf may be acceptable substitutes in some places. Early reports by investigators of littleleaf indicate that longleaf pine is infrequently affected by the disease.

Latest information concerning littleleaf is obtainable from the U. S. Bureau of Plant Industry, Soils, and Agricultural Engineering, Asheville, North Carolina.

Pitch canker has appeared on the leaders and branches, and occasionally on the main trunks, of Virginia, shortleaf, and pitch pines in North Carolina. A similar infection on slash pine in Georgia and Florida may be the same disease. The major symptom is a copious pitch flow on and below the canker. The canker retains the bark and

is always sunken over the dead area. There is no dark, discolored wood as with Atropellis cankers, little or no swelling as with southern fusiform rust, and no visible fruiting as with either of these. Pitch canker kills quicker than fusiform rust. No control is known, except prompt pruning or removal of the diseased trees, which may stop local spread (Hepting and Roth, 1946)(___).

A pine twig canker caused by Atropellis tingens Lohman and Cash occurs on all the principal southern pines except longleaf, killing some of the twigs and forming target-like, slowly growing perennial cankers on the larger branches and occasionally on the main stems. Saplings are most frequently affected. Freshly killed twigs retain their brown foliage conspicuously in the spring and early summer. Usually a persistent fascicle of dead needles is found in the center of the canker. The wood under the canker is stained bluish black. Small black fruiting bodies appearing irregularly over the canker turn green when placed in a 3 to 5 percent aqueous solution of potassium hydroxide, whereas those of other fungi remain brown or turn blue or purple. The disease, which seems to have been present for at least 50 years and to have done little harm at its worst, has seldom been reported since 1934. No control is recommended (Boyce, 1948; Diller, 1943)(___, ___).

Texas cotton root rot, caused by Phymatotrichum omnivorum (Shear) Duggar, is known to infect and kill loblolly pine planted on infected soils in Texas and southwestern Oklahoma (Wright and Wells, 1948)(___), and, apparently, planted shortleaf in Oklahoma. It has not yet proved a serious obstacle to planting, and the fungus which causes it does not occur east of Texas and southwestern Arkansas. Infected trees die suddenly, with a typical darkening and wilting of the leaves. Diseased roots are badly rotted, and they and the soil in which the injury takes place often show the buff-colored, fuzzy mycelial strands characteristic of the fungus. Means of controlling it in plantations are not known.

Enlarged lenticels frequently occur on the lower stems and upper roots of small planted pines (especially slash) on excessively wet sites. These structures are enlargements of the cell masses around the normal "breathing pores" of the stems or roots, and appear as rough, reddish-brown protuberances, sometimes separate, round, and about the size of a pin head, sometimes merging in groups that nearly encircle the root (Davis, Wright, and Hartley, 1942)(___). So far as is known, they are harmless, though indicative of adverse growing conditions. Although they look much like fungus growths or fruiting bodies, they are not caused by a fungus. They may safely be ignored.

Chlorosis or yellowing, in a mild form, often occurs on planted southern pines of all species on very wet, dry, hot, or otherwise adverse sites. It may affect all the needles simultaneously, or only the newest ones. It is caused by unfavorable environment, not

by fungi, and is distinguishable from incipient brown spot by the uniformity of the yellowing, and from needle diseases in general by the lack of browning, of lesions on the needles, and of any form of fruiting bodies. It usually corrects itself with time or changes in weather or soil moisture. No treatment is recommended or known, except possibly mulching of seedlings on severely eroded sites.

REPLACEMENT PLANTING

When early survival falls much below that anticipated, final success may hinge on replanting the fail spots. The importance of such replacement planting has become increasingly evident with realization of how much initial survival varies from place to place and year to year, and with improvement in markets for pulpwood. Replacement planting of southern pines (except longleaf) may be ineffective, however, unless made within one or at most two years after the original planting.

Whether replacement is desirable in any particular case depends to a great extent on the purpose of the plantation and on the total number of planted plus natural seedlings surviving per acre; to a lesser extent, on how the fail spots are distributed. As a rule, replacements are justifiable or essential at a higher level of survival in erosion-control plantations (Preston, 1939) (___) than in plantations for timber production; in small, intensively managed plantations (as on farms) than in large extensively managed tracts; in widely spaced than in closely spaced plantations; and when mortality occurs in blocks and patches than when it is evenly distributed. Any contractual obligation to establish a certain minimum number of trees per acre may also necessitate replacement planting.

Region 8 of the U. S. Forest Service has considered replanting only where stocking has been found by careful reexamination to be below 100 well-spaced trees per acre in the Coastal Plain and 250 per acre in other parts of the Region (U. S. Forest Service, 1939)(___). This is a somewhat arbitrary and unexacting standard, but has worked well on the National Forests because the planted areas have been large and the standard has concentrated attention on the worst failures instead of on debatable borderline cases. A minimum standard of 500 to 600 trees per acre has seemed acceptable in farm and industrial planting in Florida (Coulter, 1946)(___), and a minimum of 600 to 700 has been suggested for the Central, Piedmont, and Southern Appalachian regions (Minckler and Chapman, 1948)(___).

After the level of stocking below which replacement is necessary has been decided upon, the next two problems are to identify the plantations or parts of plantations that need replanting, and to estimate the nursery stock and labor required. A third problem is to obtain better success in replanting than in the original planting, but the only precaution requiring special mention is to replant from a few inches to a foot or two away from spots where seedlings have died, instead of in the identical spots. Except for this, improved results depend mostly upon learning the causes of the original poor survival and modifying techniques to counteract them (pp. 320 to 359).

Classifying plantations as needing or not needing replacements is practically a repetition of the planting survey (pp. 316 to 319). Estimating the stock needed usually is done simultaneously. Classification and the replacement planting itself differ from the original survey and planting mainly in requiring more careful timing. Except with longleaf, survivors of the original planting grow so rapidly in height that replanting fail spots after the second year usually is unsatisfactory. Effective classification of plantations for replacement therefore requires examination at or near the end of their second or, preferably, their first growing season. The pattern of initial survival of southern pines other than longleaf (p. 42) fortunately makes such early examinations reasonably safe guides to replanting.

In plantations of less than 200 acres, any portions needing replanting usually can be found, and their areas estimated, by rather casual inspection. Systematic cruising methods employing maps and well-distributed samples (pp. 318 to 319) are essential in most larger plantations and, if suitably intensified for small tracts, may be desirable on areas of 40 to 200 acres (Minckler, Plantation examination, 1939; Rudolf, 1950)(___, ___). Straight or diagonal rows of seedlings staked at the time of planting have proved unsatisfactory guides to the need for replacements. Such rows almost never sample the whole plantation adequately. Furthermore, they include no natural seedlings and saplings, even though these may be numerous enough, in combination with surviving planted pines, to make replanting unnecessary.

When only a few acres require replanting, the number of seedlings needed can be estimated accurately enough by eye, or can be determined by actual count. On large areas a close estimate of the stock needed is more difficult to make, and may not be worth the cost of measuring exactly the area involved and the average number of fail spots per acre it contains. Here the usual practical solution is to order stock 10 or 20 percent in excess of roughly estimated needs, replant the least well stocked areas first and the best stocked last, and plant any surplus seedlings in new areas.

Replacements in Longleaf Plantations

The low visibility of longleaf seedlings during their characteristic delay in height growth, the variation in height growth from tree to tree when it does begin, and the peculiar susceptibility of longleaf to mortality after the first year (p. 11) make it more difficult to recognize longleaf plantations in need of replanting, to estimate stock needs, and to time reexaminations and replacements, than is the case with other southern pines. The feasibility of replanting with faster growing species is reduced in many instances by the possible need for later prescribed burning to control brown spot on the surviving longleaf. To offset these difficulties, fail spots in longleaf

plantations can often be filled successfully after the second year, and irregular height growth makes stagnation of the stand unlikely even if the replacement planting results in some overcrowding.

These facts have the following practical effects on examinations of longleaf plantations to see whether replacements are needed. First, until after all the surviving seedlings have begun active height growth, it is necessary to examine individual seedlings closely, either throughout the plantation if it is small, or throughout many well-distributed sample plots if it is large; it is impossible to judge the survival of such longleaf plantations by surveying them superficially. Second, a single reexamination at the end of the first growing season is not enough; the plantation must be reexamined every year or two until sufficient seedlings to make a satisfactory stand have grown beyond reach of hogs, brown spot, and other more localized hazards (fig. 4). Third and most important, each reexamination must show the vigor as well as the number of surviving longleaf seedlings. In some cases prescribed burning may be needed to improve vigor. In many others, not only the dead but also half or more of the non-vigorous seedlings will have to be replaced. Means of telling vigorous from non-vigorous seedlings are therefore essential.

Wahlenberg has noted that longleaf seedlings rarely or never begin height growth until they are 1 inch in diameter at the ground line (Wahlenberg, 1934; Wahlenberg, 1946)(___, ___). Smaller seedlings may survive and eventually make height growth, and larger ones may succumb to brown spot or other injuries, but a ground-line diameter of 1 inch is a generally reliable and easily observed index to the imminence of height growth. It is particularly useful because it can be observed at any time of year.

From the first of December to the middle of January--even to the end of February in the northern part of the longleaf pine range and in the southern part when spring comes late--the form of the longleaf seedling bud is also a good index to the likelihood of early height growth. Buds may be classified as: (1) elongated--cylindrical, longer than thick, with pointed, conical tips,and covered with white scales; (2) round--little if any longer than thick, and covered with either hard and white or soft, felt-like brown scales; and (3) "pincushion" buds, consisting of flat discs or slightly convex masses of small, unopened needle sheaths or exposed, upward-pointing needle tips, with few or no discernible bud scales (Pessin, 1939; Wahlenberg, 1946)(___, ___).

Where brown-spot infection is moderate or light, seedlings with elongated buds are likely to make height growth within two years, often within one. Seedlings with round buds may make height growth the coming season, but are much more likely to wait two, three, or more years--during which, of course, mishaps may occur.

Seedlings with "pincushion" buds are extremely unlikely to make height growth within two or three seasons, and perhaps for much longer periods. These relationships seem to hold true regardless of the ages of the seedlings.

Where brown-spot infection is severe, seedlings with elongated buds still have good chances of beginning rapid height growth within one to three years, but seedlings with round or pincushion buds are likely to delay growth considerably longer than noted above, and many may die. Figure 44 shows the survival and height growth of longleaf seedlings in an area of severe brown-spot infection at Bogalusa, Louisiana, through the fifteenth year after planting, by bud-classes determined in February preceding the fifth growing season. Data taken 20 years after planting showed that none of the seedlings with elongated buds, a few with round buds, and about half of the survivors of the pincushion-bud class had died between the fifteenth and twentieth years.

Figure 44.--Development, by bud-classes, of planted longleaf pine, Bogalusa, Louisiana. (Solid lines, survival percent based on trees alive at start of fifth year in plantation; dashed lines, average heights of survivors.)

The degree of brown-spot infection alone, regardless of seedling bud-class or ground-line diameter, gives a good idea whether vigor will be maintained or increased or is about to decrease. In describing infection of individual seedlings, the total needle length in brown-spot lesions, brown-spot-killed tips, and needles killed outright by brown spot (including those which have dropped off), is expressed as a percentage of the total length of all needles produced during the current year. With a little practice this percentage can be estimated accurately enough by eye. Infection rates for plantations are determined by averaging the estimated infection percents of random samples of 100 or more seedlings.

The lighter the infection, the better survival will be and the sooner active height-growth may be expected. In general, seedlings with 50 percent or more of their total needle length in lesions of dead tissue are likely to decline in vigor; other levels of infection are discussed on p. 400. Estimates of infection made about December seem to give the most reliable forecasts of survival and growth. Sudden increases in the percentages of dead tissue about March or April sometimes makes spring estimates misleading, and continual development of new needles and occurrence of new infection throughout the growing season may also be confusing. At any time of year, however, the general degree of infection is useful in predicting probable future vigor.

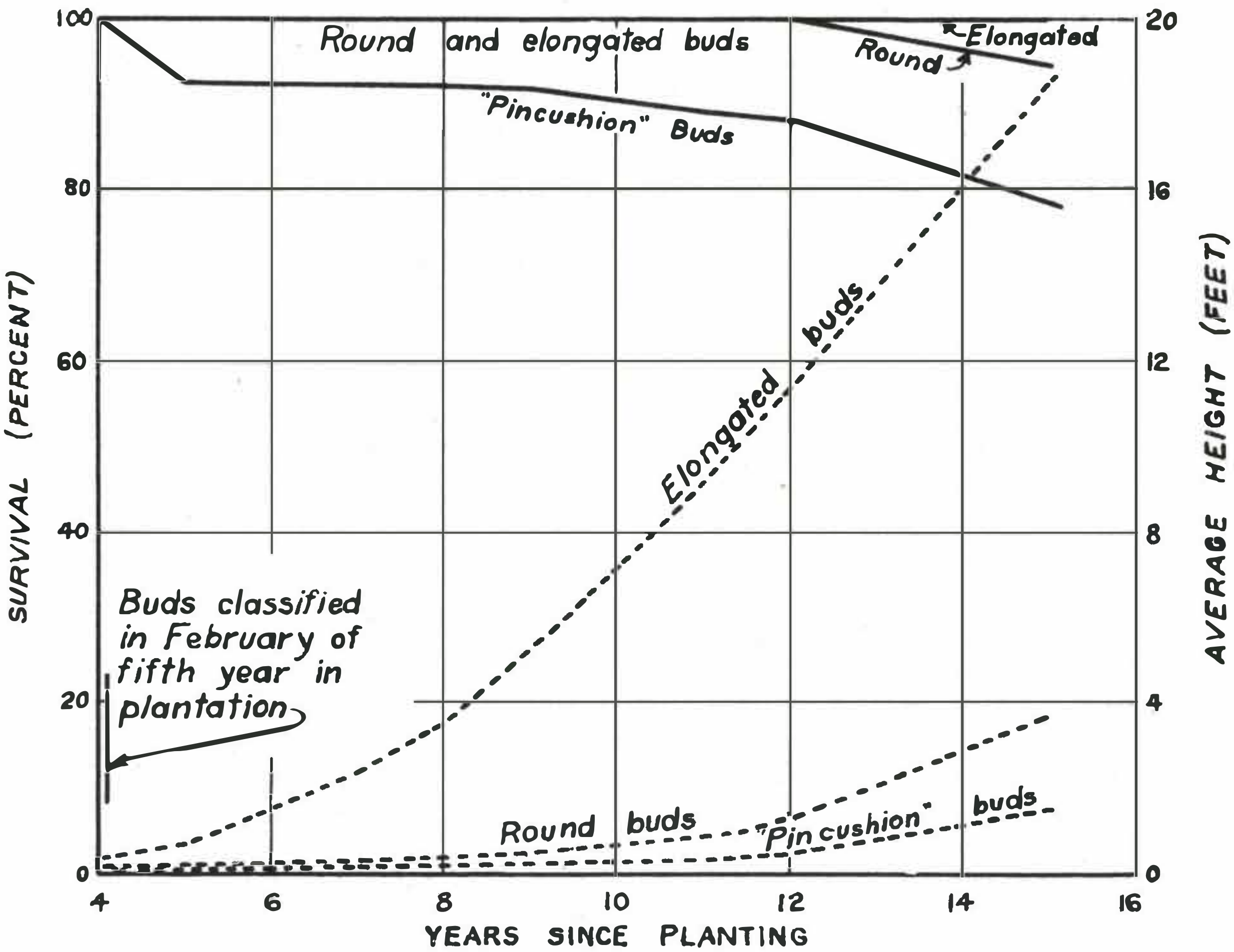

Figure 44.--Development, by bud-classes, of planted longleaf pine, Bogalusa, Louisiana. (Solid lines, survival percent based on trees alive at start of fifth year in plantation; dashed lines, average heights of survivors.)

Another index to vigor is the number of needles per bundle or sheath. Although longleaf is a "three-needled" pine, the secondary needles formed during the first year--as in the nursery--are predominately in twos. Under favorable conditions, and particularly after active height growth begins, most needles formed after the first year are in threes. On adverse sites, however, apparently in drought years, often after fires or defoliation by insects, and very frequently after repeated and severe brown-spot infection, seedlings up to a foot or more high form part or all of their new needles in twos (unpublished data). The more serious the loss of vigor, the higher the percentage of two-needled fascicles is likely to be, particularly on the smaller seedlings. The last needles formed by seedlings about to die from brown spot or other injuries frequently are of juvenile form, bluish-green in color, and single instead of in bundles (Wahlenberg, 1946)(___).

As needles can be observed the year round except right after fires, these relationships make the numbers of two-needled and three-needled bundles a useful supplement to other methods of judging vigor. In particular, a higher percentage of three-needled bundles in the newest than in the older foliage indicates increasing vigor, while a lower percentage in the newest foliage shows that vigor is declining and that the seedling may have to be replaced if growing conditions do not markedly improve.

Before they die outright from repeated, heavy brown-spot infection, longleaf seedlings from about three inches to three feet high usually show one of two characteristic symptoms of declining vigor. Either they die back from the top and form bunches of weak, two-needled or juvenile foliage along the sides and at the base, or (fig. 45) their tips remain alive but grow progressively less in height and diameter each year, forming conspicuously tapering instead of nearly cylindrical stems. When longleaf seedlings that have started height growth develop either of these symptoms, there is little hope for them. Prescribed burning to reduce the brown spot is likely to be worse than useless, because seedlings of these height classes, and seriously weakened by disease, are very easily killed by fire. Such weakened longleaf seedlings should be replaced in replanting operations, setting the new seedlings about 2 feet from the weakened old ones both to decrease infection of the new from the old and to reduce competition if the old seedlings happen to recover.

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Figure 45.--Tapering stems, poor current height growth (shown by bark rings), and meager foliage of longleaf pine seedlings after repeated heavy brown-spot infections. Such seedlings are likely to die of prescribed burning and unlikely to recover without it; in replanting, they ordinarily should be replaced.

In examining longleaf plantations for replanting, it is suggested that, to be classified as thrifty, any longleaf seedling present (whether planted or natural) should have:

a. Less than 50 percent brown-spot infection.

b. In November or December through mid-January and possibly February a round--preferably white--or elongated bud.

c. More three-needled than two-needled bundles, and especially a higher percentage of three-needled bundles in the newer than in the older foliage.

d. If more than 3 and particularly if more than 5 years in plantation, a ground-line diameter of at least 1 inch. Seedlings less than 3 years in plantation may have smaller diameters and still be classed as thrifty on other evidence.

e. No killing from the top downward and no conspicuous taper in the top of the stem as a result of repeated defoliation by brown spot.

If the plantation is young, the seedlings are small, and brown-spot infection has been heavy for only one year, prescribed burning should salvage half or more of the unthrifty seedlings. In older plantations, prescribed burning may not be feasible and up to 90 percent of the unthrifty seedlings may have to be replaced. When either brown-spot control or replanting is clearly needed, it should be carried out at the earliest appropriate time; temporizing with either may result in serious losses. Only when examination shows enough thrifty seedlings to make an adequate stand, or when neither improvement nor deterioration can be predicted reliably, should action be postponed until after a later reexamination.

Except where an important fraction of the stand has lost its resistance to fire as a result of combined brown-spot infection and height growth, there is much to be said for prescribe-burning pure longleaf pine plantations before replanting them (Chapman, H. H., "Effects of fire," 1936)(___). On large operations, where plans for replanting must be made months in advance, it may pay to burn a year before replanting. On smaller areas, burning, then reexamining, and then replanting, all in the same winter, usually is preferable. Burning makes small, surviving longleaf seedlings very much easier to see. It reduces brown-spot infection on the established seedlings, and reduces the chances of its spreading to longleaf replacements. It postpones the need for later prescribed burns and may make them unnecessary; in the latter case, it makes possible the replacement of longleaf with other species.

FERTILIZING AND CULTIVATING PLANTATIONS

With the possible exception of fertilizing longleaf to make it start height growth promptly--a technique not yet developed to the point of practicality--fertilizing and cultivating southern pines do not, in the light of present knowledge, warrant recommendation.

In most tests these practices have reduced survival, chiefly by increasing fungus infection and sometimes (in the case of fertilizing) by stimulating an excess growth of weeds around the planted trees. They have improved growth more often than survival, but apparently in no instance enough to repay the cost of treatment. There is also considerable evidence that increases in growth rate resulting from cultivation and fertilization may seriously reduce the quality of the products from the trees. Tests with other American pines and in Europe confirm these results, and suggest the inadvisability of fertilizing plantations unless a radical nutrient deficiency has been clearly demonstrated. (Balthis and Anderson, 1944; Boggess and Stahelin, 1948; Cummings, 1941; Cummings, 1945; Curran, 1936; Curran, 1938; DenUyl, 1948; Gibbs, Forest Farmer, 1948; Hendrickson, 1945; Hendrickson and Gibbs, 1949; Holsoe, 1941; Koehler, 153, 1938; Koehler, 867, 1938; McQuilkin, Jour. For., 1946; Pessin, 1939; Pessin, 1944; TVA, 1947; Wilde, Trenk, and Albert, 1942)(___, ___, ___, ___, ___, ___, ___, ___, ___, ___, ___, ___, ___, ___, ___, ___, ___, ___).

Planted slash pine should not be fertilized or cultivated where southern fusiform rust is an appreciable plantation problem, because either practice, or even planting on recently abandoned fields, has rather consistently doubled rust infection of this species (Boggess and Stahelin, 1948)(___)(Unpublished data, U. S. Bureau of Plant Industry, Soils, and Agricultural Engineering). Even in Texas, well outside the heaviest rust zone (fig. 4), cultivation of slash pine has resulted in half again more infection (Balthis and Anderson, 1944)(___). Although there is less evidence of this effect with loblolly, there is still enough to indicate similar danger in these practices, and both natural and planted old-field loblolly stands in zones of high rust hazard are notoriously likely to be heavily infected. The heavier infection of both species following fertilization or cultivation is attributed to an earlier resumption of growth in the spring by treated than by untreated trees (p. 395).

In a number of studies of cultivation and fertilization, the most effective treatment for increasing growth of longleaf pine was the complete removal of grass by hoeing (Pessin, 1939; Pessin, 1944) (___, ___). Hoeing succeeded, however, only where brown spot was held in check by spraying the seedlings several times a year with Bordeaux mixture or other suitable fungicides until they were tall enough to escape the disease. In a later and more comprehensive

study, spraying increased both growth and survival more than did any combination of hoeing and fertilization (fig. 46). It doubled or tripled survival. It increased height growth over that of unsprayed seedlings by 68 to 212 percent on hoed areas, and by 47 percent in the unmodified rough. Hoeing increased height growth substantially (more without fertilizer than with it) when seedlings were sprayed. When seedlings were hoed but not sprayed (unfertilized, denuded check, figure 46), the hoeing appreciably reduced height growth, largely because it increased infection by brown spot.

Figure 46.--Heights and survivals of variously hoed, fertilized, and sprayed longleaf pines, 7 years after planting. (Figures within bars are survival percents.)

When spraying has been omitted (in localities of brown-spot hazard), hoeing around longleaf seedlings has invariably caused a manifold increase in brown-spot infection. The intensified infection has done more harm than the hoeing has good; not infrequently it has killed the seedlings (unpublished data).

Hoeing planted longleaf in severe brown-spot areas without spraying cannot be recommended. Hoeing with spraying added seems prohibitively expensive.

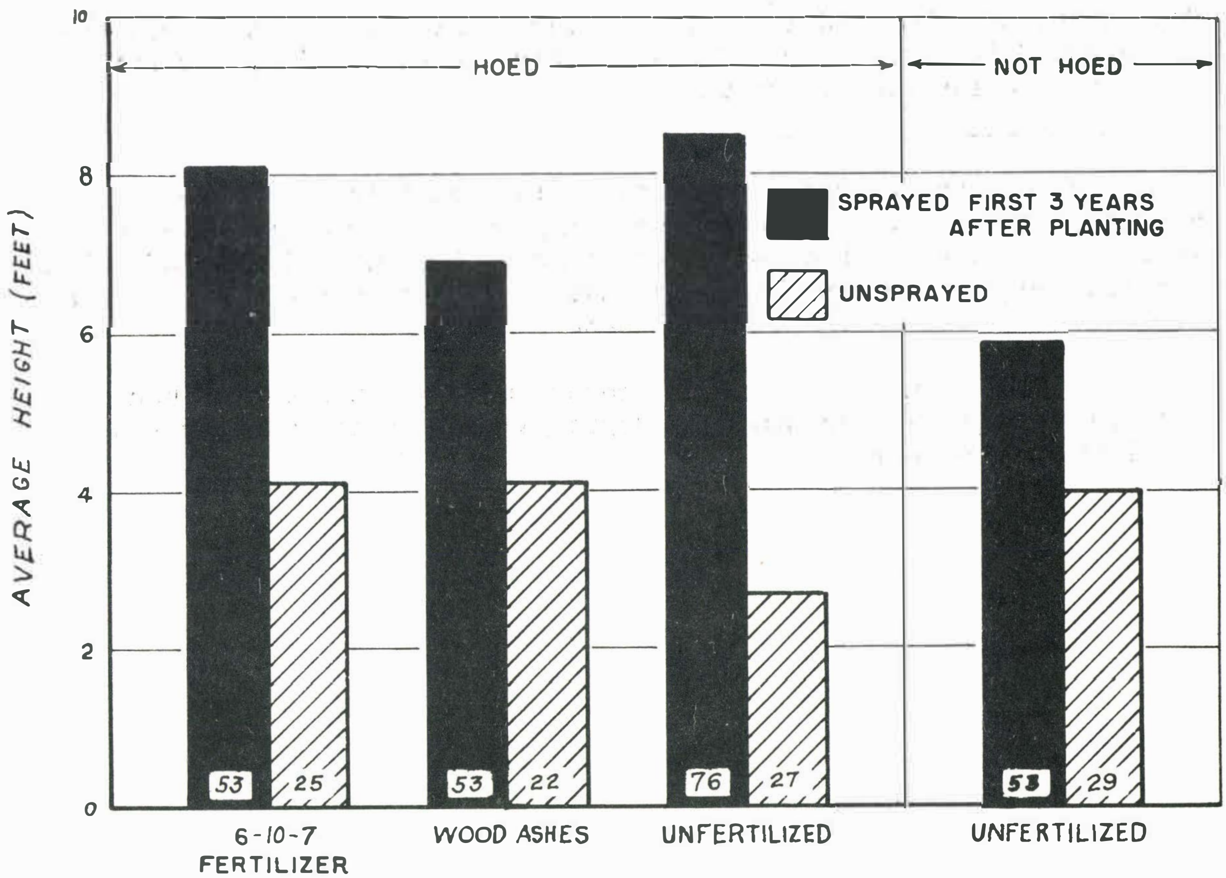

Figure 46.--Heights and survivals of variously hoed, fertilized, and sprayed longleaf pines, 7 years after planting. (Figures within bars are survival percents.)

THINNING AND PRUNING

With plantations, as with natural stands, "the ultimate total yield (including thinnings) depends on the timeliness and suitability of a series of thinnings--not on just one thinning. Within reasonable limits, single thinnings that are a little too early or too late, or a little too heavy or too light, do not give very poor results unless the same errors are repeated. If made much too late or much too early, however, the first thinning will undoubtedly reduce the eventual total yield. Hence, it is very important to make a good start. It is also important to realize that a good first thinning is not enough in itself to insure high yields, and that further thinnings must be both timely and of suitable intensity to make the most of a good start" (Bull, 1949)(___).

It is not the purpose of this bulletin to guide management beyond the first thinning, which breaks up regular plantation spacing and leaves a stand essentially like that in a well-stocked, well-managed natural forest 46/. The first plantation thinning ordinarily

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46/ A more complete treatment of thinning in general and of thinning southern pine in particular is given in (Baker, 1934; Becton, 1933; Bull, 1935; Bull, 1947; Bull, 1949; Bull, Forest Farmer, 1949; Bull, 1950; Cheo, 1946; Cheyney, 1942; Florida Forest and Park Service, 1944; Frothingham, 1941; Frothingham, 1942; Hawley, 1946; Heiberg, 1933; Howell, 1948; Kienitz by Roeser, 1931; Little, Allen, and Moore, 1948; Mar:Moller, 1947; Muntz, South. Lumberman, 1948; Reynolds, 1939; Wahlenberg, 1946; Ware and Stahelin, 1946; Ware and Stahelin, 1948)(___, ___).

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should pay for itself out of products, or even yield a profit; precommercial thinning is unnecessary except when spacing has been too close or survival very much greater than anticipated. The principal practical problems involved in the first thinning are when to make it, how much of a stand to leave, how the trees left should be spaced and arranged, and which individual trees to leave and which to cut. Like all thinnings, the first must be made with care to avoid Ips damage (p. 390), and the trees to be removed should be marked in advance.

Time of First Thinning

Southern pines planted even at the closer spacings recommended on pp. 38 to 46 do not need or justify thinning before the thir-

teenth to fifteenth year unless stagnation threatens 47/. Longleaf

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47/ The earliest evidence of stagnation (Hawley, 1946)(___) is, in southern pine plantations, a sharp decrease in diameter growth. This is followed shortly by a reduction of the live crowns of dominant and codominant trees to less than 35 percent of the total height, and eventually by the death of merchantable or near-merchantable trees from competition.

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at any of the recommended spacings and the other southern pines at the wider spacings suggested, even if survival is high, ordinarily should not need thinning before the eighteenth to twentieth year. Plantations with only fair survival may not need thinning until the twenty-fifth year unless the surviving trees are in distinct patches instead of uniformly distributed. (Bull, 1947; Bull, 1949; Bull, Forest Farmer, 1949; Florida Forest and Park Service, 1944; Gruschow, 1949; Lane and Fassnacht, 1948; Muntz, Southern Lumberman, 1948; Ware and Stahelin, 1946; Ware and Stahelin, 1948; Young, 1950)(___, ___, ___, ___, ___, ___, ___, ___, ___, ___).

Except when there is immediate danger of stagnation, no great importance should be attached to thinning the first year that merchantable products can be obtained. Ordinarily, no portion of a southern pine plantation should be thinned until the trees within it have fully occupied the ground, closed their crowns, and begun self-pruning. The wider the spacing and the lower the survival, the later planted trees will reach this stage. Furthermore, in stands ranging from 5 to about 11 inches d.b.h., yields and quality of products both from thinnings and final cuts may be increased, and costs per unit volume thinned decreased, with each inch in diameter that the trees are allowed to grow before being thinned (Muntz, Southern Lumberman, 1948)(___).

With optimum spacing, survival, and growth, need for the first thinning coincides with attainment of economical diameter for pulpwood production and with dying of lower branches of dominant and codominant trees to a height of about 35 feet; this combination should assure the maximum yield of high-quality products in the final cut. Thinning as soon as salable products can be cut may, however, be desirable to salvage infected or injured trees, or, by leaving only the sturdier dominant trees, to reduce the danger of future ice damage (Curtis, 1943; Kienholz, 1941; Lindgren, SFN, 1948; Mulloy by Luther, 1946)(___, ___, ___, ___). Despite the debris left on the ground, early thinning also appears to reduce injury from subsequent fires (Vaughn, 1934)(___).

How Much of a Stand to Leave

In thinning a southern pine plantation for the first time, it is much more important to leave the right stand per acre than to obtain any particular yield from the thinning.

Enough trees should be left to shade the ground fairly well. There should be no attempt to reduce the stand so much at the first thinning that the trees will reach final sawlog size without further thinnings; like excessively wide spacing, such heavy initial thinning wastes growing space, lowers the quality of products, and lets undesirable species invade the stand. The trees left after thinning should be able to close the crown canopy and fully occupy the site in from 5 to at most 10 years. On the other hand, they should be far enough apart so that it will take at least 3 years and often preferably 5 years (Muntz, Southern Luberman, 1948)(___) for their crowns to grow together. Cutting less heavily than this not only reduces the yield from the first thinning, but may fail to maintain desirably rapid, uniform growth by the trees left.

To meet these specifications, the stand left must ordinarily be reduced to 200 to 800 trees per acre. In stands just reaching pulpwood size, however, 200 may be too few (Gruschow, 1949)(___), and in farm plantings first thinned for pine kindling or small fence posts, it may be preferable to leave 1,000. Where trees have been planted at 6 by 8 spacing and have survived 50 percent or better, one pulp company has found the removal of 30 percent of trees, by count, in 13- to 20-year old stands, and 40 percent in 21- to 25-year old stands, a safeguard against both under- and over-thinning. In such stands, these rules leave about 300 to 550 and 270 to 460 trees per acre, respectively. In plantations spaced 6 by 6 and especially 5 by 5 feet, however, they leave far more trees, and result in under-thinning. Bull recommends thinning natural slash pine stands to 400 to 800 trees per acre if the dominant and codominant trees average 4 inches d.b.h. or 30 feet high; to 300 to 600 if the dominants and codominants average 5 inches d.b.h. or 30 to 40 feet high; and to 200 to 400 if the dominants and codominants average 6 to 8 inches d.b.h. or 40 to 50 feet high (Bull, 1949)(___).

On average sites, the first thinning of loblolly pines planted at any moderately reasonable spacing and with fair to good survival should reduce the basal areas per acre of stands with average breast-high diameters of 4,5,6,7,8, and 9 inches at least as low as 96, 105, 111, 116, 120, and 125 square feet, respectively, but not less than 60, 68, 73, 77, 80, and 84 square feet, respectively (Ware and Stahelin, 1948)(___). On average sites, more trees and larger basal areas per acre may and should be left with slash than with loblolly pine, and with longleaf pine than with either loblolly or slash (Craib by Chapman, 1947; Ware and Stahelin, 1948)(___, ___), at least at the younger ages. Slightly heavier stands should perhaps be left on very good sites, but lighter ones should be left on poor sites.

More elaborate guides (Davis, 1935; Reineke, 1933; Reineke by Schnur, 1933)(___, ___, ___) than the foregoing, although useful in developing and evaluating specifications for thinning under particular circumstances, are of little direct help in plantations. Because of the regular spacing of the planted trees, the "D + 6" and related rules (Averell, 1945; Forestry Commission by Rudolf, 1946; McIntyre, 1948; Mitchell, 1943; Mulloy, 1946; Wilson, 1946)(___, ___, ___, ___, ___, ___), are less useful in thinning plantations for the first time than in thinning natural stands.

Arrangement of Trees Left

Ordinarily, the more uniformly spaced the trees are after thinning, the better. No large openings should be made. Trees bordering existing openings should be left to extend their branches and roots into them. When several crooked or rust-infected trees occur together, the least severely injured should be left to utilize the soil and light.

In thinning extensive plantations of northern species for the first time, the difficulties of low value of products and high cost of marking have been overcome, without seriously affecting the stands left, by removing all trees in every third or fifth row, together with suitable numbers of the poorest trees in intervening rows (Luther and Cook, 1948; Spurr, 1948)(___, ___). Such row thinning appreciably reduces the total costs of both marking and cutting per unit volume removed. In certain loblolly pine plantations on Duke Forest, Durham, North Carolina, all the trees in every eighth row, together with the poorest trees in the intervening rows, have been cut in the first thinning. This permits clear-cutting the middle row of each seven remaining at the second thinning, and cutting the middle row of each three at the third thinning, together with cutting of the poorest trees present in other rows at each thinning.

Choice of Trees to Leave and to Cut

Because of the uniform initial spacing of the planted trees, the first thinning in a plantation usually requires less attention to distance between trees than does thinning in a natural stand. It gives correspondingly greater opportunity for leaving trees with superior stems and crowns.

What constitutes superior stem and crown quality will vary considerably with the purpose of planting. Straightness of trunk, superior height, good clear length, and small branches that will leave small knots are at a premium in trees to be left for saw timber, poles, and piling. Good diameter growth is desirable in such trees, but very rapid diameter growth may result in too few rings per radial

inch to meet density specifications for these products. In plantations established for pulpwood only, maximum diameter growth may be most important, small branches less important, and straightness unimportant. In plantations established for naval stores production, the best trees to leave usually are those with rapid diameter growth and long, full crowns.

Where rust infection, wind damage, ice damage, and the like are not excessive, all seriously infected and otherwise injured trees may be cut in the first thinning, if of merchantable size. Where injuries are extensive, the removal of all injured trees may leave too few stems or too little basal area per acre. Under such circumstances, freshly killed trees and trees obviously about to die should be cut if merchantable, as should very crooked trees or trees forked within the first or second log unless their removal will leave an excessive gap. Less crooked trees may be left unless their removal is desirable to make space for better trees. Trees with rust cankers on the trunk should be removed before those with cankers on the branches only; those with several trunk cankers before those with one; those with cankers running more than halfway round the trunk, or with deeply sunken cankers, or with a bend at the canker, before more lightly cankered individuals; those with low cankers before those with cankers high up. Among trees with branch cankers only, those with cankers within 15 inches of the trunk should be removed before those with cankers farther out. (Lindgren, Forest Farmer, 1948; Lindgren, SFN, 1948)(___, ___). Among wind- and ice-damaged trees, the worst bent or broken should be removed first; those most likely to regain vigor and to increase in volume and value of products should be left. Ice-damaged trees which have straightened up except for a slight curve at the base should, however, be removed as early as full use of the site permits, because the process of straightening depends on the formation of low-grade compression wood.

Excessively wide-crowned, thick-branched trees that prune themselves poorly should be removed, so far as is possible, in the first thinning, to prevent their wasting growing space. This is particularly true of loblolly pine. An exception occurs in longleaf pine plantations, in which the largest branched, widest crowned trees are likely to owe their shape to early height growth, possibly from hereditary brown-spot resistance, rather than to hereditary limbiness. Therefore, all but the very roughest of such planted longleaf trees should be left in the first thinning, even if they must be pruned.

It is questionable practice with any of the southern pines to remove the largest trees for the sake of increasing yields or labor output in early thinnings, and to leave the smallest and slowest growing trees to serve as the parents of the trees in the next rotation (Lindquist, 1948)(___). Where ice storms occur, such thinning from above may also greatly increase ice damage (p. 377).

Whether to cut or leave small trees not competing seriously with larger trees that will be left is sometimes a puzzling question (Baker, 1934; Cheney, 1942; Hawley, 1946)(___, ___, ___). If they will not directly repay the cost of cutting, they should ordinarily be left; their natural death will remove them. If they live they may help clear the trunks of neighboring trees, and may eventually grow to merchantable size. If, however, they are already large enough to pay their way, cutting them will increase the returns from the first thinning.

Pruning

Although longleaf and especially slash pines prune themselves well in reasonably close stands (Mattoon, 1942)(___) and even loblolly and shortleaf prune themselves better than the pines most frequently planted in the North (Koehler, 1936)(___), there is considerable evidence that pruning selected trees may greatly increase the profits from southern pines planted to produce saw timber (Bull, 1943; Hawley and Clapp, by Sparhawk, 1935; Mattoon, 1942; Paul, 1933; Paul by Lentz, 1938; Wahlenberg, 1946)(___, ___, ___, ___, ___, ___). Need for and returns from pruning will be greatest in plantations at wide spacing or with poor survival, or where longleaf has started height growth irregularly. Need and returns may be negligible, especially with slash pine, where spacing is close and survival good. Pruning to improve saw-log quality may, however, intensify ice damage, and should be undertaken cautiously in localities where ice storms are common.

In addition to its use for improving saw timber by reducing knots, pruning may be helpful in controlling southern fusiform rust on slash and loblolly pines, and in clearing the trunks of widely spaced longleaf and perhaps of slash for early production of naval stores.

To pay for itself, pruning for saw-log improvement must be done at a time when it will confine knots to a central core of the trunk not more than 4 or at most 5 inches in diameter, and while the branches are still not more than 1 inch to at most $2\frac{1}{2}$ inches thick 48/.

48/ A variation that shows some promise is annual removal of all buds and summer side branches above the $2\frac{1}{2}$-foot level, beginning when the trees are 3 to 5 feet high, and carrying the process to a total height of about 19 feet (Rowland, 1948)(___). Although the possibilities of this method have been little explored in the southern pine region, the longleaf pines in fig. 3 were completely bud-pruned to about 20 feet, and grew rapidly to that height with no needles except those on the main stems.

This means pruning when the trees are small, perhaps first to a height of 7 or 8 feet, and then (about 5 years later) to 17 feet. To be effective, pruning may have to start several years before thinning, though pruning to the top of the first 16-foot log may often be combined advantageously with the first thinning. Trees may be pruned to a height of $1\frac{1}{2}$ to 2 logs, but pruning to a height of 1 log seems to offer the best returns. (Bull, 1943; Lentz, Pruning, 1948; Mattoon, 1942; Paul, 1933)(___, ___, ___, ___).

For pruning to 7 or 8 feet, hand saws or close-cutting pruning shears give best results; axes, ordinary pruning shears, and clubs have proved much less satisfactory. For pruning to heights of 17 feet, hand saws used from 12-foot ladders, or saws on 9- to 12- or 14-foot poles, are about equally satisfactory, with perhaps a slight advantage in favor of the pole saws. For pruning above 17 feet, special pole saws seem superior. (Bull, 1937; Bull, 1943; Curtis, 1940; Geddes and Erickson, 1939; Hawley and Clapp, 1935; Kachin, 1940; Lentz, Pruning, 1948; Mattoon, 1942; Meyer, 1940; Moss, 1937)(___, ___, ___, ___, ___, ___, ___, ___, ___, ___). A power pruning saw, and an ingenious "push-pull" pruner effective on limbs up to 1 inch in diameter, have been described (Cuno, 1935; Rich, 1935)(___, ___), but have not come into general use.

Hand saws with straight or slightly curved blades 12 to 16 inches long and 5 to 8 teeth per inch of blade, and cutting on both strokes or on the pull stroke only, have been found satisfactory. The teeth should be long and acute, and the blade very stiff--preferably stiffer than the saws ordinarily sold for orchard pruning. Blades cutting on the pull stroke only and firmly attached to poles, but otherwise like those just described, have proved best for pruning above 7 or 8 feet. The angle of attachment should be adjustable. The poles must be light, but rigid enough to avoid springiness (Bull, 1937; Lentz, Pruning, 1948; Mattoon, 1942)(___, ___, ___). Aluminum or other light metal tubing makes the ideal pole.

With both hand and pole saws, pruning starts at the lowest branch to be cut, and progresses upward. In pruning to 17 feet at one operation, some such combination as one man with a hand saw to prune branches up to 8 feet, and two with pole saws to prune the rest, works best. With longleaf, such pruning has averaged 3 man-minutes per 4-inch tree, $4\frac{1}{2}$ per 6-inch tree, and 6 3/4 minutes per 8-inch tree, including walking time from tree to tree (Bull, 1937)(___).

There is no appreciable effect on growth of southern pines if the lower one-third of the living crown is removed at one operation. Removing more than one-third of the live crown may reduce diameter growth somewhat. There is evidence, however, that it reduces diameter growth more at breast height than higher up, and so improves the form of the trees, as Stone has reported in the case of fire (Bull, 1937; Bull, 1943; Cummings, Pruning, 1942; Diller, 1943;

Lane and Fassnacht, 1948; Mattoon, 1942; Stone, 1944)(___, ___, ___, ___, ___, ___, ___). Similar results have been obtained with other species, although some of them react less favorably than the principal southern pines to removal of one-third to one-half of the live crown (Barrett and Buell, 1938; Barrett and Downs, Jour. Forest., 1943; Buchanan, 1944; Downs, 1944; Helmers, 1946; McLintock, Note 15, 1940; McLintock, Note 21, 1940; Stephens and Spurr, 1948)(___, ___, ___, ___, ___, ___, ___, ___).

Cutting both dead and living branches flush with the trunk is imperative, as stubs, even short ones, delay healing and may permit decay. The cut should be close enough to involve the slight swelling surrounding the base of the branch; cutting into this swelling increases the size of the wound but makes it heal faster and more smoothly (Mattoon, 1942)(___).

Since pruning improves the quality of sawlogs and veneer bolts only when several inches of clear wood have been laid on over the knotty central core, it is footless to prune trees too weak, crooked, or defective to make sawlogs or bolts.

It is also wasteful to prune trees so numerous or so closely spaced that many of them must be cut for pulpwood, ties, small poles, or small rough lumber before they attain diameters large enough to pay dividends on the cost of pruning. Some allowance in number, perhaps 20 percent (Hawley and Lutz, by Littlefield, 1943)(___), should be made for infection, storm damage, and other accidents to pruned trees, of course, and for errors in judgment as to which trees will be left to form the final stand. Mattoon and others recommend pruning 150 to 300 trees per acre in young stands (Lentz, 1948; Mattoon, 1942)(___, ___), but, assuming a maximum of about 100 trees per acre at final sawlog harvest, 200 trees per acre seems the absolute maximum it would pay to prune in southern pine plantations. From 120 to 150 uniformly distributed trees of good form and vigor should be ample in most cases. To maintain uniform growth by and to insure maximum returns from the pruned trees, plantations should be thinned at fairly regular intervals after pruning for sawlog improvement.

Since profits from pruning may easily be wiped out by treating too many trees, or trees of inferior quality, it usually pays to paint-mark, in advance, the trees to be pruned. For pruning with untrained, unsupervised labor, it sometimes pays to prune all trees in every third row to a height of 7 feet, then have a qualified man go up and down the paths cleared in this manner and paint-mark suitable trees in all rows for pruning to greater heights (Crowell, 1935) (___).

Pruning off cankered branches to control fusiform rust by preventing infection of trunks (p. 396) usually must be done separately

from pruning to improve sawlog quality. To be effective, rust-control pruning usually must be done earlier, and may have to be repeated annually for as many as 5 years. Occasionally it may be included in a routine pruning to 17 feet, and sometimes it may pay to prune potential sawlog trees cleanly to 7 or 8 feet in the course of a rust-control pruning. Rust-control pruning will be most effective at least cost if all live branches cankered within 24 inches of the trunk are removed, and no other branches are cut. (Cankers on dead branches are harmless.) Evidence from several sources indicates that such pruning will seldom reduce growth (Bull, 1943; Diller, 1943; Helmers, 1946; Lane and Fassnacht, 1948; Mattoon, 1942)(___, ___, ___, ___, ___).

Although winter is the best time, southern pines apparently can be pruned safely at any time of the year except during extreme summer drought (Mattoon, 1942)(___).

SUMMARY OF IMPORTANT POINTS

GENERAL POLICIES

The four principal southern pines differ greatly in habit, growth rate, adaptability to site, and resistance to fire, animals, insects, and disease. Planting sites vary greatly in climate, soil, and the presence or intensity of insects, diseases, and other hazards. These things being so, correct choice of species for site is a necessary foundation for and a long step forward toward success. On many sites a mixture of species gives more promise than planting one species in pure stands.

Obtaining seed from the right geographic source has been shown to be vitally important with loblolly pine and may be important with other species as well. Wherever feasible, seed should be collected within a hundred miles of the planting site, certainly in a locality with a climate essentially identical with that of the planting site. Always the geographic source of the seed should be made part of the planting record.

Because of increasingly close utilization throughout the South, and to allow for mortality, planting should generally be at close spacing. Close spacing minimizes trouble with southern fusiform rust. Spacings at least as close as 8 by 8 or 6 by 8, and preferably of 6 by 6 feet are recommended, with a minimum of 5 by 5 for all species on farms, and for longleaf anywhere.

Direct seeding of southern pines has proved undependable, and often expensive. Pending demonstration of improved methods, it can be recommended only as a supplement to planting nursery seedlings, or as a gamble where severely burned-over areas must be restocked quickly with pine to forestall hardwood brush. Seed of high germination percent, and site preparation or other means to discourage birds and rodents and to insure protection against drought, appear to be among the essentials to success.

Planting costs vary so much that only those the nurseryman or planter obtains from the records of his own operations are likely to be directly helpful. Adequate records, not only of costs but also of all important points in the planting process and of local tests and innovations, are one of the surest ways of attaining good results and low costs, particularly on large operations.

SEED

Southern pines produce seed irregularly. In large operations particularly, annual estimates of cone crops are essential to economical collection, and the collection and storage of surpluses in good seed years is essential not only to reasonably low seed costs but often to any production of stock when seed crops are poor.

Southern pine cones are not mature, and should not be collected, until they will float in SAE 20 lubricating oil immediately after picking from the standing tree. Collection is cheaper from felled than from standing trees, but care must be taken not to collect from trees felled before maturity of the cones. Except in years of desperate seed shortage, wormy cones should not be collected. Needles and other trash are most cheaply removed at the collecting ground. Cones should be shipped promptly. They should never be kept in sacks more than one week. They may be precured most effectively in layers 2 cones deep, but for either air or kiln drying to extract the seed, single layers are best. Maximum temperatures recommended for drying by artificial heat are 115° F. for longleaf and 120° to 130° F. for other southern pines.

Dewinging, cleaning, and drying have been prolific sources of injury to southern pine seed, and should be planned, controlled, and checked with particular care.

Seed should be extracted as soon as possible after collection and placed immediately in dry, cold storage, not held at air temperature till spring. Even over winter, southern pine seed (especially longleaf) keeps best at a seed moisture content just below 10 percent (based on oven-dry weight of the seed), and at temperatures below 41° F. and preferably below freezing, to as low as 5° F.

Stratification of seed by chilling it in contact with moist sawdust, sand, or granulated peat is essential to prompt, complete germination of some lots of seed, unessential to others. Ordinarily, it should be applied only when advance germination tests show the need for it. Chilling for more than 10 to 20 days may be unnecessary; chilling for more than 45 days is risky with lots weighing more than 5 pounds. Temperatures should be below 41° F., but must not be below freezing.

Germination tests are essential to control seed processing and supply in general, and to economical use of seed and control of seedbed density in particular. In testing, the drawing of a sample truly representative of the seed lot is as important as germination technique. To germinate, many seed lots require some light during daylight hours

(seeds tested in sand should never be covered more than 1/8 inch deep), but direct sunlight may injure or kill seed germinating indoors. Longleaf seed germinates abnormally, if at all, if temperatures rise above 80° F.

NURSERY PRACTICES

Choice of nursery site has a major influence on the cost and success of the whole planting operation. It particularly affects cost of producing seedlings, physiological quality of stock, and the degree to which the nursery seedlings are affected by diseases such as fusiform rust and brown spot.

The larger the nursery, the lower the cost per thousand trees for modern equipment and professional supervision. The higher the degree of mechanization, including chemical weeding, the lower the cost per thousand trees shipped, except from extremely small nurseries.

Nurseries are highly individual in character, and the details of nursery technique must be developed very largely to fit the conditions peculiar to each. This is particularly true of soil fertility maintenance, which is fully as important as current seedling production. It is somewhat less true of density of stand, which usually should be between 30 and 40 seedlings per square foot.

It is foolhardy to gamble on escape from known, serious insects, diseases, or pests commonly occurring in the neighborhood or appearing in the nursery, or on non-occurrence of new pests. Prompt, correct diagnosis of any trouble and immediate action to control it are imperative.

Breakage of lateral roots during lifting is the error in nursery practice apparently most likely to reduce the initial survival of planted seedlings directly. Exposing the roots to drying for 10 minutes or more is dangerous but, with ordinary care and supervision, need not occur.

The recognition, and the production at will, of nursery stock of high physiological quality is the outstanding unsolved problem presently confronting nurserymen and nursery investigators. Granted insect- and disease-free stock with adequate lateral roots, the physiological quality of the stock appears to have more effect on initial survival than anything else under the nurseryman's control, and often far more than anything the planter does to the trees.

PLANTING

In planting, good initial survival depends primarily on: (a) avoiding excessive root exposure (including exposure in the heel-in); (b) setting the seedling at the depth at which it grew in the nursery or a small fraction of an inch deeper; and (c) closing the top of the slit or furrow tightly in bar or machine planting. All other choices, practices, decisions, or errors appear to be secondary in most cases, or to affect labor efficiency and costs rather than survival. Preparation of the site is ordinarily unnecessary except where carpet grass, Bermuda grass, lespedeza, or gallberry necessitates furrowing to reduce competition, or heavy *Andropogon* or other rough calls for burning to expedite work or get rid of cotton rats. Mulching a circle 2 to 3 feet in diameter around each tree, with pine needles or grass, seems a promising treatment on bare, eroding sites. Puddling seedling roots is unnecessary. In bar planting, having the planter carry and set his own trees greatly increases output per man-hour.

Southern pines planted under scrub oaks or other hardwoods ordinarily must be released at the time of planting or in the first to the third or fourth growing season thereafter to avoid bad delay in height growth and, in extreme cases (particularly with longleaf), heavy mortality. Poisoning the oaks with Ammate or some other chemical is a promising means of release, as it greatly reduces sprouting. An alternative method, applicable over great acreages, is to preempt the openings in the brush fields with closely spaced pine, leaving the denser thickets unplanted.

PLANTATION CARE

Advance control of injurious agents such as fire, hogs, sheep, pocket gophers, and leaf-cutting ants, and unremitting vigilance and prompt action to avoid or control other causes of injury, are essential to success. Additional major dangers are drought, ice, rabbits, southern fusiform rust (especially on slash pine), and brown spot (on longleaf). Prescribed burning to control brown spot probably is necessary to insure good survival and early height growth of planted longleaf pine at reasonable cost over much of its range.

Replacements in plantations that have fallen below an acceptable level of initial survival should be made within two years, except in longleaf plantations, which can be replanted effectively at any time up to the general commencement of height growth.

Cultivation and fertilization of plantations are not recommended. They have not been shown to repay the considerable costs involved, and they increase rust infection, especially of slash pine, in areas of high fusiform-rust hazard.

The two most essential things in the first thinning of southern pine plantations are to thin before stagnation sets in (usually while the live crowns of dominant and codominant trees still average 40 to 35 percent of the total heights), and to leave ample trees per acre for subsequent thinnings and the final crop. Slash pine is most likely to stagnate; longleaf very unlikely to. The first thinning usually involves removal of defective trees more than adjustment of spacing, and, if spacing is close and survival good, should take out most of the badly injured trees. If spacing has been well chosen, thinnings ordinarily need not and should not be made until the products cut will at least repay the cost of the operation.

When the trees are about 34 feet high, pruning 150 to 200 well-formed, well-spaced trees per acre to a height of 17 feet gives promise of greatly increasing the profits from plantations intended to produce saw timber or veneer bolts.

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APPENDICES

TABLE 27.- SOUTHERN PINES SUGGESTED FOR SITES WITHIN REGIONS OUTLINED IN FIGURE 47

SUBREGION:- Forest type formerly occupying site, or occupying similar sites nearby	Species to plant 1/	Sites 2/ which may be planted with reasonable chance of success	Sites 2/ which should be planted only on experimental scale until success has been demonstrated
COASTAL PLAIN REGION I			
Southern New Jersey Shortleaf pine; shortleaf pine-hardwoods.	Shortleaf 3/	Well drained, including dry sands.	Wet, poorly drained sites.
COASTAL PLAIN REGION II			
Maryland, Virginia, and northern North Carolina Any pine or pine-hardwood type ~~except longleaf pine on~~ deep sand-hills or pond pine 4/ on wet sites.	Loblolly	Almost any well drained or fairly well drained soil 5/.	Wet, poorly drained sites or excessively deep, dry sands.
Southern North Carolina and northern South Carolina Any pine or pine-hardwood type ~~except~~ longleaf pine on deep sand-hills or pond pine 4/ on wet sites.	Loblolly	Almost any well drained or fairly well drained soil 5/.	Wet, poorly drained sites or excessively deep, dry sands.
	Loblolly-slash mixtures	Moister sites only.	Drier sites in general, or where ice storms are frequent or southern fusiform rust infection is extreme.
North and South Carolina sandhills bordering Piedmont Longleaf pine.	Longleaf	Sites too sandy and dry for loblolly and slash.	- - -
COASTAL PLAIN REGION III			
South Carolina to Florida and west into Arkansas and Texas All loblolly, shortleaf, ~~and upland hardwood types~~, pure or in combination.	Loblolly	Almost any well drained, fairly deep soil, including many eroded and severely eroded soils.	Wet, poorly drained sites, extremely dry sites, or those with stiff clay subsoil less than 8 to 10 inches below surface.
	Loblolly-slash mixtures	Moister but still well drained sites, especially in southern and eastern extensions of types mentioned.	Drier sites, sandiest hills, or where ice storms are frequent or southern fusiform rust infection is extreme.
	Slash	Moister sites, especially east of Mississippi River. Likely to do better than loblolly on poorly drained, wet sites and on sites with stiff subsoils within 8 to 10 inches of surface.	Dry sites or sandiest hills, especially in northern extensions of types or west of Mississippi River, or in localities of frequent ice storms or extreme fusiform rust infection.
	Shortleaf	Some eroded and other drier sites in northern extensions of types and at higher elevations on former shortleaf, shortleaf-hardwood, or upland hardwood lands.	In southern extensions of types mentioned, or where littleleaf disease is prevalent.
Longleaf-slash or pure longleaf types.	Slash	On moderately moist to wet sites in former longleaf-slash types, including pure longleaf type in central and southwestern Louisiana.	On deep, sterile sands (especially western Florida sandhills), or on dry ridges north or west of native range of slash pine, or where ice storms are frequent or southern fusiform rust infection is extreme.
	Longleaf-slash mixtures	On moderately moist to moderately dry sites throughout former longleaf-slash and longleaf types.	On extremely wet or extremely dry sites, or where southern fusiform rust infection is extreme.
	Loblolly; longleaf-loblolly mixtures	On moderately moist but well drained sites without stiff subsoil or with stiff subsoil at least 10 to 12 inches below surface. Preferable to slash or slash mixtures where ice storms are frequent or southern fusiform rust infection is extreme.	On extremely wet or dry sites or those with stiff subsoil near the surface. (Mixtures containing longleaf or slash may be preferable to pure loblolly where littleleaf disease is prevalent, but longleaf should not be mixed with loblolly in areas of more than very light brown-spot infection.)
	Loblolly-slash mixtures	On moderately moist sites on which stiff subsoil lies within 10 inches of surface in some places, or where littleleaf disease is prevalent.	On extremely wet or dry sites, or where ice storms are frequent or southern fusiform rust infection is extreme.
	Longleaf	On moderately moist to driest sites formerly in longleaf pine. Has better chance than loblolly where stiff subsoils are near surface, or on deep, dry sands, and better than slash on deep, dry sands or where southern fusiform rust infection is extreme.	On very wet sites.
Southeastern Oklahoma Shortleaf, shortleaf-hardwood, ~~and upland~~ hardwood types.	Shortleaf	Practically all sites.	- - -
KIAMICHI AND OUACHITA MOUNTAINS; BOSTON MOUNTAINS; OZARK PLATEAU OF ARKANSAS			
Oklahoma and Arkansas Shortleaf, shortleaf-hardwood, and upland hardwood types	Shortleaf	Practically all sites.	- - -

TABLE 27.—(CONTINUED)

SUBREGION:- Forest type formerly occupying site, or occupying similar sites nearby	Species to plant 1/	Sites 2/ which may be planted with reasonable chance of success	Sites 2/ which should be planted only on experimental scale until success has been demonstrated
PIEDMONT			
South through Virginia 6/ Shortleaf, shortleaf-hardwood, and upland hardwood types.	Shortleaf	Practically all sites	Very wet sites, or where littleleaf disease prevails. Minckler and Chapman recommend substituting Virginia pine on areas eroded to the subsoil.
North and South Carolina 6/ Pine, pine-hardwoods, and upland hardwood types.	Loblolly	All moister, deeper soils, especially in more southerly locations and at lower elevations.	On poorly drained spots or driest sites or at highest elevations, especially in most northerly locations; on sites eroded to the subsoil.
	Shortleaf	On driest sites and at highest elevations and most northerly locations.	On poorly drained spots, or where littleleaf disease is prevalent.
Georgia and Alabama Pine, pine-hardwood, and upland hardwood types.	Loblolly	A great variety of sites, including many eroding and severely eroding ones.	On very wet sites, on very dry sites at highest elevations, and perhaps where littleleaf disease is severe.
	Loblolly-slash mixtures	Moister sites, especially near the Coastal Plain; perhaps preferable to pure loblolly where littleleaf disease is severe.	Where ice storms are frequent, or on dry sites, especially far north or at high elevations.
	Slash	On fairly moist to wet sites, especially near Coastal Plain or where littleleaf disease is severe.	Where ice storms are frequent or southern fusiform rust infection is extreme, or on dry sites, especially far north or at high elevations.
	Shortleaf	Driest sites, at highest elevations and farthest north.	On very wet sites, in southerly locations, or where littleleaf disease is prevalent.
SOUTHERN APPALACHIAN REGION			
General, including southwestern Tennessee, but excepting Alabama 6/ Hardwood and pine-hardwood types.	Shortleaf	Slope and ridge soils.	Where littleleaf disease is prevalent. Minckler and Chapman recommend substituting Virginia pine above 2,500 feet, and eastern redcedar on pure limestone areas.
Southeastern Tennessee only Hardwood and pine-hardwood types.	Loblolly	Moister, deeper soils. Loblolly may be better than shortleaf on such sites, especially where littleleaf occurs.	Drier sites at higher elevations.
Alabama Any other than longleaf pine types.	Loblolly	A great variety of sites.	Extremely wet or dry sites or sites at high elevations.
	Shortleaf	Driest sites and those at highest elevations.	Where littleleaf disease is prevalent.
Longleaf pine types.	Loblolly or longleaf-loblolly mixtures	Best and deepest soils, with stiff subsoil at least 10 to 12 inches or underlying rock at least 24 to 30 inches below surface. Mixture preferable where littleleaf disease is prevalent.	Very wet or dry sites. On sites containing appreciable areas of shallow surface soil, longleaf-loblolly mixtures may be preferable to pure loblolly.
	Longleaf	A great variety of sites, especially those with stiff subsoils only a short distance beneath the surface.	Very wet sites.
SOUTHERN CENTRAL REGION			
General, except western Tennessee 6/ Shortleaf, shortleaf-hardwood, and upland hardwood types	Shortleaf	Practically all slope and ridge soils, including severely eroded soils. (Most planting of southern pine in this region is on abandoned fields.)	On wet upland flats.
Western Tennessee Pine, pine-hardwood, and upland hardwood types.	Loblolly	Moister, deeper soils; many of more fertile though badly eroded soils in silt-loam uplands.	Driest sites; severely eroded areas east of silt-loam uplands.
	Shortleaf, or loblolly-shortleaf mixtures	Drier sites, and badly eroded sites east of silt-loam uplands.	Very wet sites.

1/ Where mixed planting is suggested, mixtures of 3 rows or 5 rows, or in checkerboards of 9- or 25-tree squares, ordinarily are preferable, regardless of species. Longleaf pine in particular should never be planted in single-row or individual-tree mixture with other species.

2/ None of the principal southern pines may be expected to do well on very brushy sites unless the sites are specially prepared before planting or the planted trees are later released from competition; see pp. 323 and 332.

3/ A conference of forestry agencies in New Jersey recommends loblolly as well as shortleaf pine for all but the driest sands, and for some sites too poorly drained for shortleaf (Lentz, 1948)(____).

4/ Information (Pruitt, 1947)(____) on planting the pond pine type is too limited for general recommendation.

5/ But on former longleaf sites on which a stiff subsoil lies 8 inches or less below the surface, longleaf may do better than loblolly.

6/ Adapted from Minckler and Chapman (Minckler and Chapman, 1946)(____).

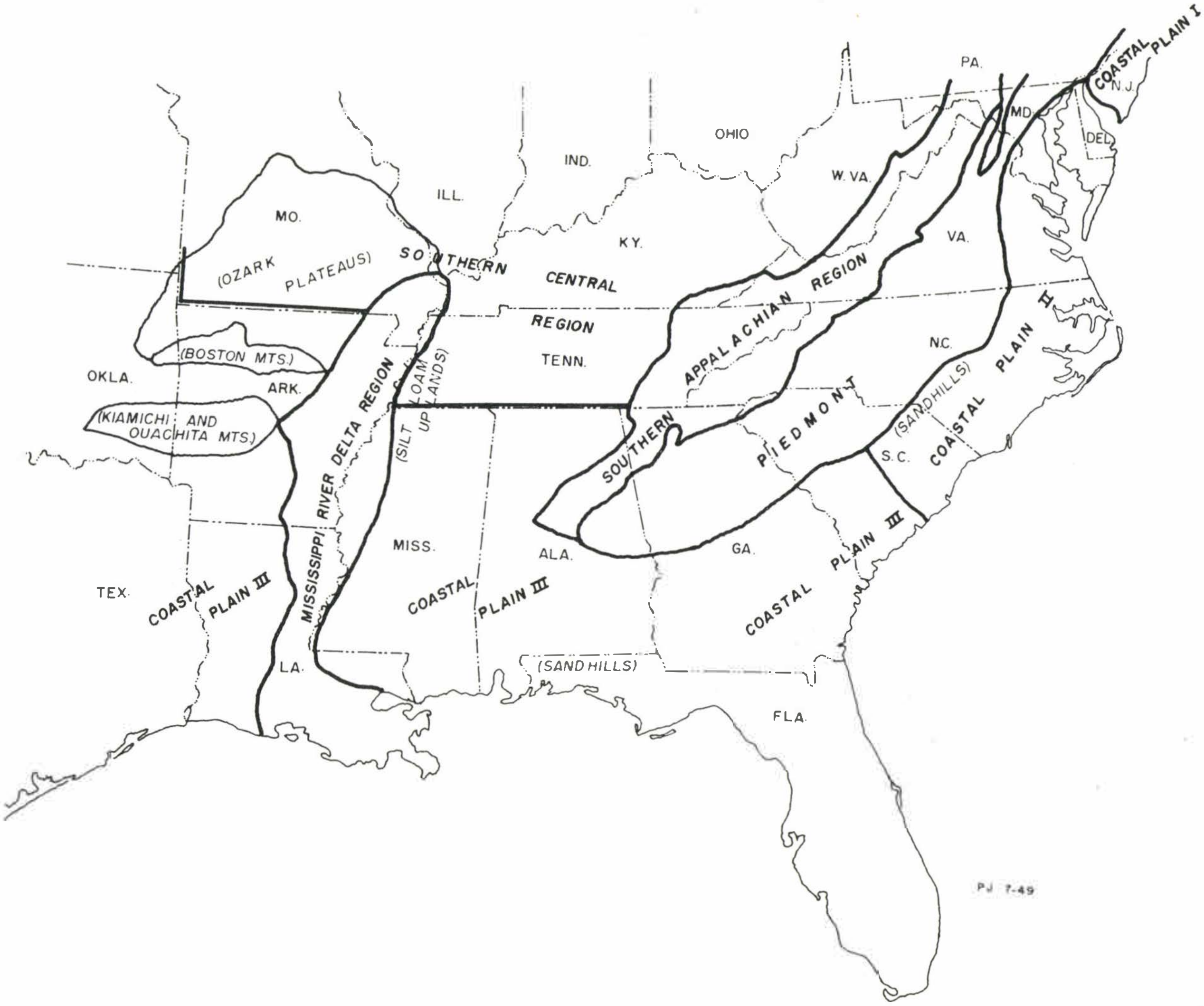

Figure 47.--Regions distinguished in suggesting southern pines for planting on various sites (table 27), as shown by (Fenneman, 1938, and Minckler and Chapman, 1948)(___, ___) and unpublished data.

TABLE 28.–SOUTHERN PINE CONE AND SEED DATA [1]

ITEM OF INFORMATION Purposes for which most often needed	Species	Mean or most common choice	Range [2]
		- - - - Number - - - -	
UNOPENED CONES PER BUSHEL. Estimating cone crops and cone requirements.	Longleaf	100	60 to 120
	Slash	200	160 to 240
	Loblolly	500	400 to 1,080
	Shortleaf	2,000	1,450 to 2,500
FULL SEEDS PER CONE. (MEANS ARE FOR GOOD SEED YEARS; MAY BE 1/2 OR LESS IN POOR YEARS.) Estimating cone requirements; checking quality of sample cones cut open before collection.	Longleaf	50 to 60	1 to 150 or more
	Slash	60 to 70	1 to 100 or more
	Loblolly	40 to 50	1 to 200
	Shortleaf	25 to 35	1 to (undetermined)
		- - - - Pounds - - - -	
YIELDS OF COMMERCIALLY CLEANED SEED PER BUSHEL OF UNOPENED SOUND CONES [3]. (MEANS ARE FOR GOOD SEED YEARS; MAY BE 1/2 IN INTERMEDIATE AND 1/4 IN POOR YEARS.) Estimating cone requirements.	Longleaf, wings on	1.2	0.30 to 1.5
	, wings reduced	1.0	.25 to 1.4
	Slash	1.0	.25 to 1.5
	Loblolly	1.0	.25 to 1.5
	Shortleaf	.8	.20 to 1.4
		- - - - Inches - - - -	
LENGTHS OF CONES. Gaging distances between cone trays in tiers. (Distances should at least equal maximum cone length; fixed shelves should be farther apart.)	Longleaf	6.0	4.0 to 10.0
	Slash	3.5	2.3 to 6.0
	Loblolly	3.0	1.8 to 6.0
	Shortleaf	1.9	1.1 to 2.8
DIAMETERS OF UNOPENED CONES AT THICKEST PART. Selecting the wire or spacing the slats for cone trays, shelves, and tumblers, or for chutes to separate opened from unopened cones.	Longleaf	2.0	1.6 to 2.7
	Slash	1.6	1.3 to 1.8
	Loblolly	1.2	.7 to 1.7
	Shortleaf	.8	.5 to 1.1
		- - Square feet - - - -	
SPACE REQUIRED TO SPREAD 1 BUSHEL OF UNOPENED CONES IN SINGLE LAYER. Designing cone trays; estimating drying or precuring space for cones.	Longleaf	8.	6.4 to 8.8
	Slash	10.	8.0 to 11.0
	Loblolly	15.	12.0 to 16.5
	Shortleaf	20.	16.0 to 22.0
		- - - - Number - - - -	
SEEDS PER POUND [4]. Estimating seed requirements; gaging sizes of seed samples; calculating sowing rates	Longleaf, wings on	4,200	3,800 to 6,000
	, wings reduced	4,700	4,200 to 6,700
	Slash	14,500	13,000 to 16,000
	Loblolly	18,400	16,000 to 25,000
	Shortleaf	48,000	36,500 to 62,500
		- - - - Grams - - - -	
WEIGHTS OF 100-SEED SAMPLES. Drawing subsamples from sacks or cans; setting up germination tests.	Longleaf, wings on	10.8	7.6 to 11.9
	, wings reduced	9.6	6.8 to 10.8
	Slash	3.1	2.8 to 3.5
	Loblolly	2.5	1.8 to 2.8
	Shortleaf	.9	.7 to 1.2
		- - - Inches - - - -	
WIDTHS OF SEEDS AT WIDEST POINT. Selecting wire mesh for drying-shed shelves, cone trays, and cone tumblers; selecting cleaning-mill screens; seed identification.	Longleaf, wings on	.45	.30 to .60
	, wings reduced	.26	.20 to .35
	Slash	.18	.16 to .22
	Loblolly	.16	.12 to .18
	Shortleaf	.12	.10 to .14
LENGTHS OF SEED WITHOUT WINGS. Designing germination-test equipment; seed identification.	Longleaf	.40	.30 to .50
	Slash	.28	.24 to .32
	Loblolly	.24	.22 to .26
	Shortleaf	.20	.18 to .22
MESHES OF SQUARE-MESH WIRE TO PASS SEEDS WITH WINGS. Designing extractory shelves, cone trays, cone tumblers.	Longleaf	1/2	[5] 1/2 to 3/4
	Slash	1/2	[5] 1/2 to 3/4
	Loblolly	1/2	[6] 1/3 to 1/2
	Shortleaf	1/2	[6] 1/3 to 1/2
MESHES OF SQUARE-MESH WIRE TO STOP SEEDS WITH WINGS OFF. Designing extractory shelves, cone trays, and trays for drying seed.	Longleaf	1/8	1/16 to 1/8
	Slash	1/8	1/16 to 1/8
	Loblolly	1/16	1/16 to 1/12
	Shortleaf	1/16	1/16 only
		- - 64ths of 1 inch - - - -	
UPPER SCREENS IN SEED-CLEANING MILLS. Ordering and operating cleaning mills.	Longleaf, wings on	32	30 to 32 by 48 oval
	, wings reduced	28	24 to 32 by 48 oval
	Slash	16	14 to 18
	Loblolly	14	12 to 16
	Shortleaf	10	10 to 12
LOWER SCREENS IN SEED-CLEANING MILLS Ordering and operating cleaning mills	Longleaf	16	8 to 16
	Slash	8	6 to 10
	Loblolly	6	6 to 8
	Shortleaf	6	6 only

1/ These values have been derived from data obtained in many different studies, not from systematic surveys throughout the southern pine region. Deviations from the means, and occasional extremes beyond the stated ranges, must be expected.

2/ In cone and seed dimensions, most minima and maxima represent <u>means of samples</u> of unusually small or large cones or seed, not smallest or <u>largest individual</u> cones or seeds observed.

3/ Yields from wormy cones may be only 1/3 to 1/2 as much.

4/ Based on 100-percent pure seed, fanned to remove empty seeds to the extent feasible in commercial practice. Moisture content typically 10 to 13 or 15 percent.

5/ With ordinary galvanized hardware cloth, mesh at least as close as 3/4 inch is needed to support the weight of cones on wide trays or shelves.

6/ Meshes 3/4-inch wide or wider will pass the smallest unopened cones of this species.

DESCRIPTIONS OF EXPERIMENTAL PLANTING AREAS

Table 29 gives the geographic locations and chief climatic conditions of the principal experimental planting areas from which the data in this bulletin have been drawn. Further details are:

Bogalusa Experimental Plantations

The Coburn's Creek and Upper Coburn's Creek Experimental Plantations, totaling 14.5 and 7.0 acres respectively, have been the principal source of detailed data from Bogalusa, Louisiana. They are $\frac{1}{4}$ mile apart, in Section 5, Township 3 South, Range 13 East (Louisiana Base Line and St. Helena Meridian), about 4 miles northwest of Bogalusa, on the southwest side of the Bogalusa-Franklinton Highway. The Coburn's Creek Plantations were established by the Southern Forest Experiment Station in 1924-1925 through 1926-1927; and the Upper Coburn's Creek in 1925-1926 through 1926-1927. Some information has also come from 4 acres of loblolly spacing plantations established in 1922-1923, about 2 miles south in Section 17 of the same township. All these plantations were established and have been maintained on the lands and with the cooperation of the Great Southern Lumber Company and its successor, the Gaylord Container Corporation.

The area is within the Upper Coastal Plain. Detailed soil maps of the Coburn's and Upper Coburn's Creek areas prepared in 1924 and 1925 show Myatt very fine sandy loam, Kalmia very fine sandy loam, and negligible areas of other soils on the less well drained portions of the Coburn's Creek area, and Susquehanna and Norfolk very fine sandy loams in all the better drained portions of the Coburn's Creek area and all of the Upper Coburn's Creek area except one poorly drained corner occupied by Myatt very fine sandy loam. The outstanding characteristic of the soil on all but the poorly drained portions is the presence of a stiff sandy clay or clayey sand from 12 to as little as 4 inches below the sandier surface soil. Such soils are typical of millions of acres of cut-over land, formerly in pure longleaf pine, from Alabama to Texas inclusive.

The Coburn's Creek area lies about one-third on a flat but well-drained ridge top, one-third on a broad, uniform slope of 4 to 5 percent, and one-third on a moderately to poorly drained flat next to Coburn's Creek. Terrestrial crawfish are abundant on the poorly drained flat. The Upper Coburn's Creek area straddles a low, flat-topped, well-drained ridge, and slopes off to either side with a maximum gradient of 3 to 4 percent; one corner lies in a wet spot. The loblolly spacing plantations in section 17 lie near the foot of a long, uniform 3-percent slope.

Table 29.--Locations and approximate elevations and climatic conditions of principal experimental planting areas mentioned in text 1/

Item and unit	Bogalusa	J.K.Johnson Tract	Harrison Experimental Forest	Auburn, Alabama
Location	Washington Parish, Louisiana	Rapides Parish, Louisiana	Harrison County, Mississippi	Lee County, Alabama
Latitude	30° 49' N	31° 11' N	30° 36' N	32° 36' N
Longitude	89° 55' W	92° 41' W	89° 04' W	85° 30' W
Elevation above sea level (feet)	130-150	160-260	70-110	680-700
Temperature (degrees F)				
Mean annual	68	67	67	65
Mean January	52	51	53	50
Mean July	82	82	82	80
Frost-free period (days)	255	255	270	235
Precipitation (inches)				
Mean annual	61	55	62	52
April through September	34	27	34	24
June through August	18	14	19	14
Mean relative humidity, noon, June (percent)	62	60	63	59

1/ Climatic data interpolated from maps in (U. S. Dept. Agr., 1941) (___).

All three areas originally bore heavy pure stands of large longleaf pine. They were logged in 1918 to 1920, with steam skidders. Fires were common until 1920, when fire protection was begun and the areas were fenced against hogs. There have been no fires since 1920, except on one quarter-acre at Coburn's Creek, burned over annually during 1921 through 1924, as part of a firebreak. A few cattle have grazed the areas annually since planting.

When planted, the three areas were open grassland, in which Andropogon scoparius was the dominant species; with it were associated A. tener and many other grasses and broadleaved herbs, including pitcher plants on the least well drained spots at Coburn's Creek. At planting time there were only negligible hardwood sprouts and brush. Since planting, oaks, hollies, dogwood, blackgum, and sweetgum, a little yellow-poplar, other hardwood tree species, some wax myrtle and other brush, and dense thickets of gallberry and of blackberries have invaded most of each area.

All the experimental planting at Bogalusa was done in furrows plowed 1 week to 15 months before planting.

The Bogalusa plantations are just inside the northwestern limit of the natural range of slash pine. They are outside the ranges of pocket gophers and Texas leaf-cutting ants, and well beyond the southeastern zone of deficient spring rainfall, but are within the zones of maximum brown-spot and fusiform-rust infection. Rabbit damage was variable but often moderately severe during the establishment of the plantations. Tipmoth injury to loblolly and shortleaf was very severe in the 1920's and early 1930's. Glaze storms have been rare and not of maximum severity, but one in December 1929 severely injured slash pine in spots.

Within a radius of 15 miles of the Coburn's Creek plantations are about 57,000 acres of commercial plantations (p. 59), on sites similar to but more varied than those just described. These have been an invaluable additional source of general and specific information.

J. K. Johnson Tract Plantations

These consist of about 750 acres, or about three-quarters of a million trees, planted by the Southern Forest Experiment Station with CCC and WPA labor on the J. K. Johnson Tract of the Palustris Experimental Forest, in the Evangeline Division of the Kisatchie National Forest, from 1934-1935 through 1940-1941 inclusive. The Tract includes all of Section 4, Township 2 North, Range 3 West, and some of Sections 33 and 34, Township 3 North, Range 3 West (Louisiana Base Line and Meridian), a total of about 1,200 acres lying about 17 miles southwest of Alexandria, Louisiana, on State Highway 278.

The tract is in the Upper Coastal Plain. In 1916 the Bureau of Soils mapped most of the soil in Section 4 as Ruston fine sandy loam, and most of that in Section 33 as Susquehanna very fine sandy loam. The soil is much more variable than these classifications suggest. Much of that in Section 4 is like the better-drained soils of the Bogalusa areas, with a stiff subsoil underlying a sandier surface soil at 4 or 6 to 12 or rarely 18 inches. Some flat ridge tops, however, are of silty, poorly drained soil, excessively wet at most seasons, but dust-dry to great depths in abnormally dry summers. The only crawfish noted have been on these ridge tops. Narrower, steeper-sided ridges, mostly in Section 33, are of coarse, sandy soil to a depth of at least 30 inches, and well or excessively drained. There are some outcrops of gravelly clay. There are many flats (on ridge tops) and many slopes of 1 to 5 percent, with a few short slopes of 12 to 15 percent. Despite this variation, the soils on the greater part of the tract resemble those of the better-drained portions of the Bogalusa area, and represent millions of acres of cut-over longleaf pine sites from Alabama to Texas.

The whole Johnson Tract, except for one or two small drainage ways, originally supported a heavy stand of pure longleaf pine. Section 33 was logged with teams about 1906; Section 4 (fig. 48) with steam skidders about 1917. Fire protection was lacking until the late 1920's and imperfect until 1933. Fire and hog protection were fairly complete from 1934, when experimental planting began, until World War II terminated planting in 1941. Fire and hog damage during the war were severe.

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Figure 48.--Portion of J. K. Johnson Tract in 1937. Natural reproduction from the scattered longleaf trees left uncut in 1917 has been negligible.

When planting began, the Johnson Tract was open grassland except for a few residual longleaf pines, scattered and in clumps, a little natural longleaf reproduction, and some hardwood sprouts, a few big patches of scrub oak, and hardwoods and loblolly and shortleaf pine near one drainage way. _Andropogon scoparius_ predominated among the grasses, with _A. tener_, _A. elliotti_, _A. virginicus_ and many other grasses and herbs intermixed. There were large patches of pure _A. tener_, however, and, on variations from the prevailing soils, distinct grass associations: mixed tall grasses in the vegetated draws; _Panicum_ spp. on the flat, poorly drained ridges, and much _Muhlenbergia_ spp. on the drier, steeper sand ridges. Scattered yucca plants and dwarf sumacs usually grew with the Muhlenbergia on these sands. The sites on which planted pines survived and grew best could usually be picked in advance of planting by their 8 to 12 or more inches of sandy loam surface soil over fairly heavy subsoil, and by the denser and taller cover of _Andropogon scoparius._ Brush invaded the Johnson Tract plantations much less rapidly than those at Bogalusa, and gallberry does not occur on the Johnson Tract.

Except in site-preparation experiments, no seedlings on the Johnson Tract were planted in plowed furrows.

The Johnson Tract is about 150 miles west of the natural range of slash pine. It is within the range of pocket gophers and Texas leaf-cutting ants, both of which interfered seriously with experimental planting until controlled. Rabbits did intermittent damage during planting. Brown-spot infection has been severe, though less so than at Bogalusa. Fusiform-rust infection was relatively light at the start of planting, but has increased. Tipmoth damage has been less severe than at Bogalusa. Glaze storms have been more frequent and more severe than at Bogalusa, with bad ones in 1943-1944, 1946-1947, and 1950-1951. As shown by table 29, the summers are drier than at Bogalusa; summer droughts tend to be more frequent and prolonged.

Plantations on the Harrison Experimental Forest

With two or three minor exceptions detailed elsewhere, these plantations, totalling about 55 acres, were established by the Southern Forest Experiment Station in 1940-1941, with WPA labor, in the eastern half of Section 14, Township 5 South, Range 11 West (St. Stephens Base Line and Meridian), just west of State Highway 55, on the Biloxi District, DeSoto National Forest.

The area is within the Upper Coastal Plain. Most of the soil in the plantations was mapped as Ruston fine sandy loam or Orangeburg fine sandy loam by the Bureau of Soils in 1924. In general it is representative of the better cut-over longleaf pine sites, with 8 to perhaps 15 inches of fine sandy loam over a friable to fairly stiff clayey sand or sandy-clay subsoil. All is nearly level to gently sloping, and generally well drained; crawfish have not been noted. When planted, most of the area was cut-over land, never cultivated, variously burned and later protected, and moderately grazed, largely open, partly brushy. The best soils had been farmed at irregular intervals, in irregular patches abandoned from 2 to 10 or more years before planting. Some of these abandoned fields retained furrows; all varied one from another in vegetative cover--ragweed, *Andropogon virginicus*, carpet grass, *Panicum* spp., or blackberries--depending on past history. The portions not cultivated were quite uniformly in *Andropogon scoparius* and associated species typical of cut-over longleaf land from Alabama to Texas. Some gallberry was present, but did not increase as rapidly as at Bogalusa during the first 10 years after planting.

None of the 1940-1941 Harrison planting was in furrows. Initial survival on about one-third of the area was seriously reduced by too long storage of the planting stock.

The Harrison experimental plantations are well within the range of slash pine, but there is little natural slash pine on the site. The plantations are outside the ranges of pocket gophers and Texas leaf-cutting ants, within the same zone of adequate spring and summer rainfall as the Bogalusa plantations, and in an area of somewhat less severe brown-spot infection and tipmoth infestation and of possibly less severe fusiform-rust infection than the Bogalusa plantations. Brown-spot and rust infections on the Harrison have nevertheless been heavy; rust infection on slash pine planted on abandoned fields has consistently been about twice as heavy as on the same species planted on land never cultivated. Rabbits did little damage in 1940-1941. Glaze storms have been a negligible hazard.

Experimental Plantations at Auburn, Alabama

The Auburn plantations were established by the former Department of Horticulture and Forestry, Alabama Polytechnic Institute, at various times from 1928 through 1941, on almost unclassifiable soils transitional between Upper Coastal Plain and Piedmont, in Sections 25 and 36, Township 19 North, Range 25 East (St. Stephens Base Line and Meridian), on the Institute's experimental farm in the outskirts of Auburn, Alabama. The original forest, before clearing many years ago, was mixed longleaf, shortleaf, and loblolly pines, with considerable intermingled oak and hickory. At the time of planting, the area was a miscellany of variously farmed out, eroded, and abandoned old fields and waste ground between fields. The sites are far less typical of cut-over longleaf pine land and more representative of many loblolly-hardwood sites than those at Bogalusa, on the Johnson Tract, and at the Harrison. Some slopes at Auburn, although not excessive, are steeper than any of those on the other three areas. There are few, if any, poorly drained spots.

Auburn is fully 60 miles north of the natural range of slash pine (Weddell, 1939)(___). It is outside the ranges of pocket gophers and Texas leaf-cutting ants. Brown spot has done some damage, but has been distinctly less severe than in the other experimental plantations described, especially those at Bogalusa. Fusiform rust is much less severe than in the Bogalusa and Harrison plantations, and apparently less severe than it has recently become in the Johnson Tract plantations; cultivation of slash pine after planting, even on old fields, has nevertheless approximately doubled infection (Boggess and Stahelin, 1948) (___). Data on tipmoth and rabbit damage are not available, except that such damage evidently has not been a major problem. Glaze storms are fairly frequent, but have not struck the experimental plantations very hard. These plantations are within the littleleaf zone, near the point of original discovery of the disease, and near areas of maximum littleleaf injury to older shortleaf and loblolly pines.

SAFETY RULES FOR THE USE OF INSECTICIDES, FUNGICIDES, BAITS, AND REPELLENTS

Most insecticides and fungicides as well as some other sprays and baits contain poisons injurious, if not deadly, to humans and livestock. Many act through the skin or lungs as well as through the digestive tract. In addition, some are inflammable or explosive, or involve other hazards.

Unless a substance is known to be perfectly harmless, every care should be taken to avoid accidents arising from its use. Furthermore, prevention of serious injury or loss of life may require correct action within minutes, or even seconds, if accidents do occur.

Proper precautions against accidents require: (a) correct information on the part of foremen and crew; (b) thorough training and supervision of the crew; and (c) the right equipment, properly maintained.

To reduce risk to the minimum, not only the foreman but also every man in the crew must know what to do in case of accident. This knowledge enforces respect for the materials used and reduces the danger of accidents. Surgical supply-house charts telling what to do in case of poisoning and burns should be kept posted in equipment and supply buildings, together with manufacturers' warnings about and antidotes for the specific poisons used. These should be studied till memorized, and foremen and workmen who apply insecticides and the like should be drilled in the treatment for poisons and burns, and for injuries to the eye (American Red Cross, 1945)(___). These inexpensive precautions may easily prevent work stoppages, damage suits, and unnecessary suffering or even death.

Enforcing the following general rules (Anonymous, Safety Rules, 1947; Parker, 1943)(___, ___) should minimize accidents with poisons and other hazardous materials.

1. Plainly mark both temporary and permanent containers to show nature of contents (poisonous, inflammable, or the like) and date of purchase (some chemicals change or deteriorate with age). Keep dangerous materials tightly closed (unless their nature requires venting); out of reach of children, irresponsible persons, livestock and pets; and in an adequately ventilated storeroom, preferably locked.

2. When mixing or applying poisonous materials, take extreme care to keep them out of mouth, eyes, nose, and lungs and away from tender parts of the body. Ordinarily, wear leather or paraffined-cloth gloves (rubber or plastic gloves must be used with certain chemicals), and always wear goggles, respirator, or a combination of the two if the substance requires. If manufacturer specifies, mix substance only in open shed or outdoors.

3. Prohibit smoking during the mixing or application of inflammable or explosive substances.

4. Burn or bury empty packages and bags that have contained poisons. Bury unused or discarded materials. When mixing vessels, sprayers, and the like are washed after use of the more poisonous substances (such as sodium fluosilicate), empty wash-water into hole in ground, and fill in the hole. Do not burn empty arsenical containers except in open air.

5. Always wash hands and face thoroughly after mixing or applying poisonous substances. After long exposure, bathe and change clothes. Wash the clothes after each day's spraying operation.

6. Make sure that no poisonous spray material can in any way get into domestic or livestock water supplies.

7. If sulfuric acid must be diluted (as for acidifying soil to control damping-off), always pour the acid, which is the heavier liquid, into the water. Water poured into sulfuric acid spatters badly, with serious danger, especially to the eyes.

INSECTICIDES 49/

49/ Much of the information concerning these and not credited to other sources is from Entoma (Amer. Assoc. Ec. Ent., 1947; Amer. Assoc. Ec. Ent., 1949)(___, ___). Current editions of Entoma are convenient sources of trade names and ingredients of insecticides, and of companies supplying them.

The insecticides discussed here have not been equally well proved by use in the southern pine region. Local experience, manufacturers' directions, or published reports must be expected to improve choice or dosage (particularly of the new synthetic organic multipurpose insecticides) in some instances. Whenever the threat of immediate loss from insects is not excessive, unproved treatments should be tried experimentally before being applied wholesale.

Within the 5 general classes which follow, insecticides are listed alphabetically.

Multipurpose Insecticides

The new synthetic organic insecticides introduced into general use during or since World War II, although sometimes called contact insecticides, seem better classed as multipurpose insecticides because numbers of them also act as stomach poisons and some as fumigants.

In general these insecticides are complex chemicals, notable for the low dosages required per acre, their effectiveness against many different insects, and their ability both to reach and to control important pests relatively unaffected by older insecticides. Some, however, are ineffective against certain common pests, or even cause them to increase (DDT does this with red spider and some aphids), apparently by killing predators or parasites of the pests while leaving the pests uninjured. The multipurpose insecticides seldom require spreaders or stickers, as these are granulated into the commercial products; also, many have inherent residual effects, particularly valuable in controlling insects that subsequently hatch in or migrate into the treated area. Many are extremely toxic to humans, and, as a general rule, precautions must be taken to keep sprays and especially oil emulsions containing these insecticides from getting on the skin, and to wear respirators when measuring, mixing, or applying the insecticides as powders or dusts.

It should also be pointed out that DDT and BHC are of variable effect and by no means uniformly successful. Their effectiveness in controlling many insects depends on proper timing. The U. S. Bureau

of Entomology and Plant Quarantine, or the appropriate State plant quarantine and nursery inspection official (p.536) should be consulted concerning timing of treatment.

Benzene hexachloride (BHC; hexachlorocyclohexane; one trade name of a dust, "Lexone 50").--For aphids, grasshoppers (for which it excels DDT), harvester ants, mole crickets, and white grubs, and many caterpillars and adult beetles. It contains several isomers, of which only the gamma isomer is effective insecticidally, and the gamma isomer content should, therefore, be ascertained before purchase or use. Available in wettable powders containing at least 6 to 10 percent of gamma isomer; in dusts containing 2.5 to 12.0 percent of gamma isomer. Dosages of 0.25 to 1.25 pounds of gamma isomer per acre (up to 20 pounds of dust per acre, depending on concentration) are effective. Promptness of kill and extent of residual effect reported variable. Harmfulness to plants, in dosages required for insects, apparently somewhat variable; reported less dangerous to operators than some other multipurpose insecticides. (Anonymous, "Illinois", 1948; Brett and Rhoades, 1946; Hill and Hixson, 1947; Kyd, undated; List and Hoerner, 1947; Weihung and Hoerner, 1947; Wilson and Choudhri, 1948)(___, ___, ___, ___, ___, ___, ___).

For mole crickets, 50 percent wettable powder containing 6 percent of gamma isomer is reported as a promising spray (Kelsheimer, 1947)(___).

For white grubs, the North Carolina Division of Forestry and Parks has found it effective to apply one of the more concentrated wettable powders at the rate of 20 pounds per acre, when damage by grubs appears, and wash it in with the sprinkling system.

Chlordane.--For ants, aphids, grasshoppers (for which it excels DDT), mole crickets, white grubs, caterpillars in general, some leaf miners, possibly nematodes. It is a liquid in pure form, but is available in various concentrations of dusts, wettable powders, and emulsions. The dusts are applied as they come from the package. The wettable powders are sprayed in mixture with other water-wettable-powder sprays by use of conventional sprayers only, and emulsion sprays with either conventional or mist type sprayers. Usual dosages are 1 or at most 2 pounds of actual chlordane per acre. (One quart of 50 percent emulsion, or 2 pounds of 50 percent wettable powder, or 10 pounds of 10 percent dust, applied per acre, give 1 pound of actual chlordane per acre, whether diluted much or little.) It has been reported as a relatively slow killer, at least for grasshoppers, with 10 or more days' residual effect. (Anonymous, "Floridians", 1948; Anonymous, "Illinois", 1948; Chadwick, 1948; Hartman, 1948; Kyd, undated; List and Hoerner, 1947)(___, ___, ___, ___, ___, ___)

For harvester or mound-building ants, insert 1/8 teaspoonful of 50 percent powder in a hole in each hill (Chadwick, 1948)(___).

For mole crickets, spray with 1 pound of 50 percent wettable powder per 100 gallons of water, or make up into 5 percent bait, as directed by manufacturer (Anonymous, "Floridians", 1948)(___).

For white grubs, apply 20 pounds of 50 percent powder per acre ($\frac{1}{2}$ pound per 1,000 square feet) as a spray, or mix with sand and work into the soil dry.

Chlorinated camphene (Toxaphene).--Reported effective for ants, grasshoppers, mole crickets, most caterpillars, and possibly for nematodes; for grasshoppers, at least, a slow killer, with 10 or more days' desirable residual effect. Available in various concentrations of non-wettable dusts, wettable powders, and emulsions. For grasshoppers, dust or spray at convenient dilutions to give $1\frac{1}{2}$ to $2\frac{1}{2}$ pounds of actual chlorinated camphene per acre. For other pests, see manufacturers' directions. (Anonymous, "Floridians", 1948; Kyd, undated)(___, ___).

DDD (Dichloro-diphenyl-dichloroethane; also referred to as TDE; one trade name is Rothane).--Closely related to DDT, and useful in general in same way; specifically reported as effective against mole crickets. Chief advantage over DDT is its lower toxicity to humans. Apply according to manufacturers' or State agricultural experiment stations' directions. (Kelsheimer, 1947)(___)

DDT (Dichloro-diphenyl-trichloroethane).--For ants, Colaspis beetle, crawfish, some cutworms, grasshoppers (but less effective than either chlordane or benzene hexachloride for grasshoppers), mole crickets, pine webworms, sawflies (for which it excels lead arsenate), some scale insects, tip moths (including Nantucket), white-fringed beetle (most effective treatment yet reported for this insect), white grubs, and miners, suckers, and borers generally. It increases injury by red spiders and is ineffective against, or actually causes increase of, some aphids.

It comes in non-wettable dusts or powders, wettable powders, ready-to-use oil-based sprays, and oil-, xylene-, or other emulsion concentrates, all of varying concentrations of actual DDT. The less concentrated dusts are applied as they come from the package; the more concentrated require dilution with inert dusts. Solutions made with the wettable powders should be applied with conventional sprayers only, not with fog sprayers or mist blowers; sprays prepared with emulsions appear applicable in almost any manner except with fog machines. Dosages usually are reckoned in pounds of actual DDT per acre. One pound of actual DDT per acre is a common dosage for many insects feeding on above-ground parts of plants; and 10 to 50 pounds of actual DDT sprayed on or worked into the soil, for soil-inhabiting insects. For applications not calculated by acreage, thorough wetting with a 1 percent solution is frequently recommended. Most concentrations effective against insects are harmless to plants, but on some plants certain oil sprays cause injury if used after DDT. DDT in oil preparations is

readily absorbed through the skins of humans and other warm-blooded animals, with possible serious injury; such absorption through the skin should be avoided, and the dust should not be inhaled. (Anonymous, "Civilians", 1945; Anonymous, "European elm scale", 1947; Anonymous, "Peach scale", 1947; Anonymous, "Huntsville", 1948; Anonymous, "Illinois", 1948; Anonymous, "Long Island", 1948; Afanasiev and Fenton, 1947; Cummings, M. B., 1946; Davison, 1947; Gilgut, 1948; Hartman, 1948; Kelsheimer, 1947; List and Hoerner, 1947; Weihung and Hoerner, 1947)(___, ___, ___, ___, ___, ___, ___, ___, ___, ___, ___, ___, ___, ___, ___)

For control of Colaspis beetle from the ground, thorough coverage with 1 percent emulsion or suspension in water is suggested; for possible airplane spraying, 1 pound actual DDT in 1 gallon of oil per acre.

For crawfish, spray whole cottonseed, or coarsely ground corncobs thoroughly with 2.5 percent solution of DDT; scatter $1\frac{1}{2}$ bushels of cottonseed or 100 pounds of ground corncobs per acre whenever damage occurs; treatment is most effective in warm, rainy weather. A single sprayed cottonseed dropped in a burrow will kill the crawfish in it. (Davison, 1947)(___)

For mole crickets on small areas, add 1 to 4 pints of 25 percent DDT in emulsion concentrate to 100 gallons of water and apply to soil with sprinkling can at rate of 1 gallon of mixture to 10 square feet of soil, to give about 10 to 40 pounds of actual DDT per acre. On large areas, apply 150 pounds of 20 percent DDT dust (30 pounds of actual DDT per acre) with fertilizer, before sowing, and work into top few inches of soil; increase dose slightly if mole crickets are very numerous. Neither treatment should injure plants; each will stimulate mole crickets to excessive activity for a day (a sign the insecticide is working) but should render them harmless in 2 to 3 days, and also control ants and cutworms. (Kelsheimer, 1947)(___)

For pine webworm, spray with 1 percent emulsion.

For sawfly larvae, spray thoroughly with 0.5 to 1.0 percent DDT emulsion or suspension in water, or apply at the rate of 0.5 to 1.0 pound of actual DDT per acre. (Anonymous "Civilians," 1945; Kowal, 1948)(___, ___)

For scale insects. The effectiveness of DDT on scale insects attacking southern pines appears not to have been reported, but its 2 to 3 weeks' residual effect makes it better than oils or nicotine sulfate for some scale insects, including pine-leaf scale on ornamental pines. Thorough application of 1.0 percent solution (16 pounds of 50 percent wettable powder in 100 gallons of water) is reported effective against European elm scale, a species notoriously difficult to control (Anonymous, European elm scale, 1947; Gilgut, 1948)(___, ___).

For Nantucket tip moth or other shoot moths in plantations, spray thoroughly with 0.5 to 1.0 percent solution of DDT in water early in each of first two flights of the year (Afanasiev and Fenton, 1947)(___), or, for more certain control, when moths of each flight first appear and again 10 days later (Anonymous, "Long Island", 1948) (___). Airplane application of 0.5 to 1.0 pound of DDT per acre of plantation has also been proposed; for maximum effectiveness it would have to be made early in flight of adults. DDT appears highly successful against tip moths generally (Anonymous, "Civilians", 1945)(___), and spraying or dipping nursery stock with 1.0 percent DDT emulsion before shipment should be as effective as and cheaper than the white-oil-emulsion or nicotine-oleate dips.

For white-fringed beetle, work 10 to 50 pounds per acre of actual DDT into the top few inches of soil, if possible in successive applications of 0.5 to 1.0 pound every 2 weeks rather than all at once. Some effects of treatment persist 2 to 5 years; 50 pounds per acre should give virtually complete control for 2 years. (Anonymous, "Huntsville", 1948)(___). These applications have been reported non-injurious to plants; 1/3 to 1 pound of actual DDT per acre of foliage has been reported to kill 90 percent of adult beetles, with great reduction of later populations of larvae.

Although not explicitly reported for southern conditions, control of white grubs by working about 20 pounds of actual DDT per acre (5 pounds of 10 percent powder per 1,000 square feet, or 200 pounds per acre) is suggested (Cummings, M. B., 1946)(___).

HETP or HEPT (Hexaethyl tetraphosphate; trade names: Hexide, Hexate, Killex, Vapotone).--Insecticides containing this basic chemical are reported effective against aphids, red spider, and many other insects, and against young scale insects when mixed with DDT. Erratic, toxic to warm-blooded animals and dangerous to operator (requiring mask and rubber gloves), and corrosive to galvanized equipment. It contains about 15 percent of TEPP as the principal active ingredient; TEPP content must be stated on label. Available in water-soluble and emulsifiable forms. Apply at rate of 0.5 pint per 100 gallons of water, or according to manufacturers' directions. (Anonymous, HEPT, 1947; Gilgut, 1948; Hartman, 1948)(___, ___, ___)

Parathion (Trade names: E-605, Parathion 3422, Thiophos, Thiophos 3422, 3422).--Particularly effective on aphids and red spider; also used on grasshoppers, leaf miners, soft scales, and some beetles, leafhoppers, moths, and many other insects. It smells like garlic or onions. It is available in prepared dusts, and wettable powders; 15-percent and 25-percent wettable powders are usually sprayed at the rate of 1 pound per 100 gallons of water (minimum, 2 ounces; maximum, 2 pounds), and 2 or 4 pounds of 25-percent wettable powder may be combined with 100 pounds of inert dust to make 0.5 to 1.0 percent dust. Reported relatively or wholly non-injurious to plants, including evergreens, unless used in connection with Bordeaux (an important point in southern pine

nurseries); safest not to use in connection with any other spray material. Residual effect for 5 to 15 or more days, killing delayed arrivals and late-hatching eggs. Deadly to higher animals and humans; use fullest precautions, including respirator, in measuring, mixing, and applying. (Anonymous, "Floridians", 1948; Anonymous, "Long Island", 1948; Anonymous, "Parathion", 1948; Kelsheimer, 1948; Leiby and Ward, 1948)(___, ___, ___, ___, ___)

TEPP.--Contains 40 percent tetraethyl pyrophosphate, HETP, as the principal active ingredient. Particularly effective for aphids and red spider. May injure plants treated with copper in any form (as Bordeaux). Poisonous; use with extreme precaution. For application, follow manufacturers' directions.

Fumigants

In seed, nursery, and planting practice in the southern pine region, fumigant insecticides have been used primarily to control soil-inhabiting insects; less frequently, to control nematodes.

Calcium cyanide (one trade name, Cyanogas).--See hydrogen cyanide.

Carbon disulfide (also referred to as carbon bisulfide; known locally as "high life.").--For harvester ants, various mound-building ants, Prionid larvae, Texas leaf-cutting ants, and white grubs in nurseries, and Texas leaf-cutting ants in plantations.

Carbon disulfide is a volatile liquid and very inflammable; its vapor in mixture with air is highly explosive. Safe handling requires transportation in tightly closed containers kept as cool as possible (not exposed to sun), no smoking, and strict avoidance of open flames or electric sparks. Effectiveness against soil insects results in part from weight of vapor, $2\frac{1}{2}$ times that of air.

For controlling Prionid larvae and white grubs in nurseries after damage appears, pour or inject 1.2 cc of carbon disulfide per hole in $\frac{1}{2}$-inch holes punched in the soil to depth of 3 to 4 inches, 6 inches center to center (equivalent to 1 pint per 100 square feet), when soil is moist but not wet (maximum moisture content about 15 percent), at a temperature (top 6 inches) of at least 78° F., and loose and friable; plug each hole tightly with soil immediately after injection. To avoid injury to seedlings, make holes between drills, do not water within one hour after injection, and do not inject immediately before or after rain. Straight carbon disulfide applied in this way has proved more manageable and less injurious than carbon disulfide emulsion flooded on the bed surface (Johnston and Eaton, 1939; Johnston and Eaton, 1942) (___, ___).

For harvester or mound-building ants in nursery beds, apply as above, or punch holes well into the mounds or burrows and pour in up to an ounce or two of carbon disulfide per mound, sealing the holes immediately (Fla. Dept. Agr., 1938)(___).

For control of Texas leaf-cutting ants see pp. 577 to 579.

Chloropicrin.(Chlor-picrin, Larvacide, and other trade names).--Chloropicrin is a heavy, colorless (or slightly yellowish) liquid, almost insoluble in water but soluble in alcohol, gasoline, and other organics, and readily volatilizing into "tear gas" heavier than air. It is effective against cutworms, white grubs, nematodes, and soil fungi. Because it is extremely irritating it is best measured out in open air, and injected with hand or power applicators (McCallan, 1948) (___).

Requirements for treatment are quite exacting. It must be applied 5 to 24 (usually 7 to 10) days before crop is sown; soil must be permeable but not too loose, moderately moist, and moderately warm (60° to 85° F. is about optimum); application of 1 to 3 cc per hole in holes 3 inches deep (5 to 6 inches on lighter soils) and 8 to 10 inches center to center (rates per acre quoted: 33 to 41 gallons, or 230 to a maximum of 740 pounds); holes must be closed immediately after injection, and soil sealed with water at rate of about 1 quart per square foot of bed surface. (Manufacturers' specifications; unpublished data). Even when so applied, and with sowing deferred till 3 weeks after treatment, it may cause some injury to southern pine seedlings.

Cyanamid (trade name for mixture of calcium cyanamide, hydrated lime, carbon, calcium carbonate, and calcium sulfate).--For nematodes, recommended at rate of 1 ton per acre, applied dry, well worked in and washed in with water 6 to 8 weeks before sowing, and recultivated repeatedly, between application and sowing; even with these precautions sometimes injurious to crop plants and, therefore, preferably applied before soiling crop. (Fla. Dept. Agr., 1938)(___). Appears not to have been tried on southern pine seedbeds.

Ethylene dichloride.--Ethylene dichloride injected into soil like carbon disulfide for white grubs, but at rate of 1 gallon per 100 square feet, may control white grubs effectively after they appear in the nursery (Johnston and Eaton, 1942)(___).

Ethylene dibromide (trade names: Dowfume W40, Dow W-40, Garden Dowfume, Iscobrome D).--For white grubs and nematodes. A liquid, sometimes diluted with naphtha. It is applied 1 to 3 weeks before sowing as specified by the manufacturer (Cummings, M. B., 1946; McCallan, 1948)(___, ___). Dow W-40 applied in the manner and at the rate described for chloropicrin appears to have been effective against nematodes in southern pine seedbeds.

Hydrogen cyanide.-- Hydrogen cyanide, or hydrocyanic acid gas, because of its extreme toxicity and the difficulty of applying it under nursery or plantation conditions, has apparently not been used directly to control southern pine pests. It is liberated, however, from calcium cyanide upon exposure to moist air, and calcium cyanide (obtainable in dust, granule, or flake form under the commercial name of Cyanogas) has effectively controlled harvester or mound-building ants when sealed into ½-inch by 12-inch holes punched into their nests.

Methyl bromide.--Methyl bromide (trade names: Dowfume G and Iscobrome) has proved equal or superior to carbon disulfide for control of Texas leaf-cutting ants in plantations (Johnston, 1941; Johnston, 1944)(___, ___) and seems a promising alternative to carbon disulfide for control of Prionid larvae, white grubs, and various ants in nursery beds, especially as it may be obtained in 1-pound sealed units, with applicators. For white grubs or ants, apply like carbon disulfide. It is described as controlling nematodes, as having relatively low toxicity to growing plants, and as being applicable as a soil treatment as little as a week before sowing.

For control of Texas leaf-cutting ants, see pp. 577 to 579.

Sodium cyanide-ammonium sulfate treatment for nematodes.--Well in advance of sowing, apply 600 pounds of sodium cyanide per acre; irrigate or wash in thoroughly; immediately (at the very latest the same day) apply 900 pounds of ammonium sulfate per acre and wash into the soil even more thoroughly. The whole effectiveness of the treatment rests upon applying ammonium sulfate immediately after the sodium cyanide; there must not be delay, nor must the two substances be mixed before application, because what kills the nematodes is the chemical reaction of the two substances in the soil. For absolute eradication, double the quantities stated. (Fla. Dept. Agr., 1938)(___). The treatment is expensive but may be well justified for controlling localized outbreaks before they spread.

Contact Insecticides

Contact insecticides are used to control pests with sucking mouth-parts (aphids, red spider, scale insects, and the like) which are not affected by stomach poisons. Thorough coverage at the right stage in the insect's development is essential to success, as is avoidance of solutions injurious to the pines. If used in combination with other substances, they should first be tested on small plots, as some oils used as contact sprays cannot be applied after DDT or sulfur, without injuring the foliage of some plants (Anonymous "Peach scale Control", 1947)(___).

See also multipurpose insecticides, but note that DDT cannot be used to control red spider and some aphids because it increases injury.

Bordeaux mixture.--A fungicide (see p. 524) rather than insecticide, but frequently recommended for red spider. Apply in ordinary strength, but heavily enough and under enough pressure to insure thorough coverage.

Cubé ("koobay") and derris powders.--Organic insecticides, useful alone or with wettable sulfur for controlling red spider. Apply according to manufacturer's directions.

Lime-sulfur.--Suggested at rate of 1 gallon of liquid commercial concentrate (density about 30° Baume) to 100 gallons of water to control red spider (Fla. Dept. Agr., 1938)(___). Lime-sulfur also may be mixed from prepared powders (commercial dry lime-sulfur, 2 pounds; Santomerse S, ½ pint; water, 50 gallons) or in other ways (as hydrated lime, 5 pounds; dusting sulfur, 4.6 pounds; ortho-spreader, 0.5 pound; water, 50 gallons). Occasionally used for pine-needle scale (Anonymous, "Long Island", 1948)(___) but the stronger solutions (1 part to 8 or 9 of water) frequently recommended for dormant sprays for various scale insects on deciduous trees. It has been used against many sucking insects, particularly scale insects, but probably cannot be used on pines without seriously burning the foliage (Doane, Van Dyke, Chamberlin, and Burke, 1936; Graham, 1929)(___, ___).

Lubricating oil emulsion (with nicotine sulfate).-- For scale insects.

Lubricating oil	1 gal.
Soap (kind unspecified; divide finely if not liquid)	7¼ lbs.
Nicotine sulfate	½ lb. (½ pt. if liquid)
Water	50 gals.

Emulsify thoroughly by pumping back on itself. Apply freshly mixed, to scale insects immediately they appear.

Miscible oil emulsions (White oil emulsions; one trade name, Volck).--For scale insects and for tip moths in the egg or early larval stages.

The miscible oils are much more convenient contact insecticides than lubricating oil, and are less likely to burn the foliage. They are self-emulsifying with water but some of them separate in the container and require stirring before mixing with water. They may be used at the rate of 1 or 2 parts to 100 parts of water (for small lots, 1.28 fluid oz. per gallon of water), alone or with nicotine sulfate (usually 1 pint of nicotine sulfate to 100 gallons of water), or with nicotine sulfate plus soap, or according to manufacturer's directions. The brands supplied in thick or paste-like condition should be mixed thoroughly with a small portion of the total water required, before the final mixture is attempted. (Baumhofer, 1936)(___)

As a dip for tops of seedlings to kill tip-moth eggs and small larvae on nursery stock:

Miscible oil or miscible oil emulsion	1 part
Water	100 parts

One gallon of the mixture treats up to 1,000 seedlings (Baumhofer, 1936)(___).

As spray for scale insects, applied at first appearance of scales:

Miscible oil or miscible oil emulsion	1 gal.
Soap (dissolve completely in water)	$7\frac{1}{4}$ lbs.
Nicotine sulfate	$\frac{1}{2}$ lb. (or $\frac{1}{2}$ pt.)
Water	50 gals.

Nicotine dust.--For aphids. (Doane, Van Dyke, Chamberlin, and Burke, 1936)(___). Apply according to manufacturer's directions.

Nicotine oleate.--A dip for seedling tops to kill tip-moth eggs and small larvae on nursery stock.

Make stock solution by thoroughly mixing 10 parts by volume of 40 percent free nicotine solution (not nicotine sulfate) with 7 parts of commercial oleic acid to form a soft soap. For dipping-mixture, dilute 1 part of this stock solution with 46 parts of water, thoroughly mixing stock solution with small portion of water before mixing with whole. One gallon of 40 percent nicotine plus 0.7 gallon of oleic acid makes a final mixture for about 40,000 trees at most (Baumhofer, 1936) (___).

Nicotine sulfate.--For aphids, red spider, and scale insects. The usual commercial form, sold under a great variety of trade names, is a 40 percent solution. Dilute at rate of 1 part to 800 or 1,000 parts of water (1 pint to 100 gallons of water, or $1\frac{1}{4}$ to $2\frac{1}{2}$ teaspoonsful to a gallon); 1 part to 500 parts of soapy water for scale insects. Two ounces to 3 pounds of soap per 100 gallons of water greatly increases the effectiveness of the nicotine sulfate. (Doane, Van Dyke, Chamberlin, and Burke, 1936; Graham, 1929)(___, ___). (See also lubricating and miscible oil emulsions.)

Rotenone.--The principal toxic constituent of cubé and derris powders.

Sulfur.--Available as a fine powder for dusting, alone or with equal quantities of hydrated lime, or as a special wettable sulfur powder for application alone or with wettable cubé or wettable derris powder, for red spider. One recommended combination is 4 lbs. wettable sulfur, 4 lbs. wettable cubé (or derris) powder, and 100 gals. water,

applied with power sprayer (Anonymous, "Red spider," 1947; Fla. Dept. Agr., 1938)(___, ___).

Stomach Poisons Used Mostly as Foliage Sprays

Arsenate of lead or lead arsenate.--For sawfly larvae, *Tetralopha* larvae, adult *Colaspis* beetles, adult May beetles, and miscellaneous chewing beetles, most caterpillars, and leaf-chewing insects generally. (Relatively ineffective for cutworms and grasshoppers.) See also multipurpose insecticides.

Use acid lead arsenate ($PbHAsO_4$), not basic. Since forest insects seem to require heavier dosages than agricultural crop insects, mix in the proportions of 2 pounds of powder or 3 pounds of paste to 50 gallons of water (for small lots, 6 teaspoonsful per gallon). Add hydrated lime, in weight equal to that of the lead arsenate, if necessary to prevent burning foliage. A spreader or sticker usually improves results. (Erambert, 1940; Graham, 1929; Middleton, 1927; Snyder, 1940) (___, ___, ___, ___)

Calcium arsenate.--Calcium arsenate seems not to have been used to control insects on the foliage of southern pines. Before it is applied wholesale, it should be tried on test plots, to make sure it does not burn the foliage.

¶ One ounce of calcium arsenate in each ant nest has been recommended for harvester ants in nurseries, if carbon disulfide cannot be used.

Stomach Poisons Applied as Baits

Poisoned baits may be the only recourse if cutworm or mole cricket outbreaks occur after nursery beds have been made, or when cutworms attack seedlings after secondary needles have appeared. For early season control, see multipurpose insecticides. Grasshopper baits are useful when the newer insecticides are unavailable.

For cutworms 50/.--To be effective, cutworm bait must be dry

50/ Sodium fluosilicate (Na_2SiF_6) is recommended as a replacement for sodium arsenite and arsenic trioxide in cutworm and grasshopper baits (Amer. Assoc. Ec. Ent., 1949)(___), and has replaced them in Government baiting programs. See manufacturers' directions or consult the U. S. Bureau of Entomology and Plant Quarantine for latest dosages.

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enough to crumble readily after having been squeezed in the hand, but not too dry to cling together in flakes when scattered. It should be

scattered at the rate of 15 to 20 or even 30 pounds of dry ingredients per acre. It must be used early in the outbreak, before the cutworms complete their damage and stop feeding, and must be scattered after or shortly before sundown, because cutworms are night feeders.

In the formulae given, shorts, rice bran, or alfalfa meal may be substituted for wheat bran, and cottonseed meal may be substituted for half the bran (Crumb, 1926)(___). The poisons mentioned appear to be interchangeable; calcium arsenate and lead arsenate, however, are relatively ineffective against cutworms (Crumb, 1926; Lincoln and Isley, 1945)(___, ___) and should not be substituted in the formulae; white arsenic (arsenic trioxide) should be used only in very finely powdered form, as ordinary granular white arsenic is unsatisfactory (Crumb, 1926)(___).

For early season controls, see DDT and benzene hexachloride.

Formula 1. (Walton, 1946)(___).

Ingredient	Large lot	Small lot
Wheat bran	50 lb.	1 peck
Paris green or white arsenic	2 lb.	$\frac{1}{4}$ lb.
Water	1 gal. or more	2 to 4 qts.

Mix dry ingredients thoroughly; add water, stirring vigorously, until uniformly of right consistency. Works better if allowed to stand for several hours before being scattered.

In the large lot, 25 pounds of hardwood sawdust (pine sawdust seems to repel cutworms) may be substituted for 25 pounds of the wheat bran, if 2 quarts of molasses is added by stirring it into water before adding liquid to dry ingredients.

Formula 2. (Lincoln and Isely, 1945)(___).

Ingredient	Large lot	Small lot
Bran	100 lbs.	1 lb.
Sodium fluosilicate or Paris green	4 lbs.	1 heaping teaspoonful
Water	8 to 12 gals.	4/5 pint

Mix as in formula 1.

For grasshoppers 50/.--

Formula 1. (Parker, 1939)(___).

Mill-run bran, mixed feed, or shorts	25 lbs.
Sawdust (3 times bulk of bran), about	3.5 bu.
Liquid sodium arsenite (32 percent arsenious oxide)	0.5 gal.
Water	10 to 12 gals.

The bran component may be replaced with another bushel of sawdust (total 4.5 bu.) if 1.5 gallons of molasses (low grade cane or blackstrap) is added.

Formula 2. (Fla. Dept. Agr. 1938)(___).

Bran	20 lbs.
Paris green (preferred) or white arsenic	1 lb.
Syrup	2 qts.
Lemons	3
Water	$3\frac{1}{2}$ gals.

Mix dry ingredients, then stir into them the mixture of water, syrup, and squeezed and finely chopped lemons.

White arsenic and sodium arsenite (the so-called 4-pound commercial grade containing 4 pounds, or 32 percent, of arsenious oxide to the gallon) are about equally effective killing agents in grasshopper baits, but lead arsenate is not. Any sawdust may be used; the finer, cleaner, and older it is, the better. Any addition of bran or of dried, ground citrus pulp improves sawdust, and such citrus pulp mixed with unground cottonseed hulls is a good carrier (Walton and Whitehead, 1945) (___). Scatter grasshopper bait at rate of 10 to 15 pounds per acre, wet weight, at dawn or shortly thereafter, as grasshoppers feed in daytime only.

For other controls, see chlordane, chlorinated camphene (Toxaphene), and benzene hexachloride.

For mole crickets (Wisecup and Hayslip, 1943)(___).--

Wheat bran (dry)	100 lbs.
Sodium fluosilicate	8 lbs.
Water	3 to 5 gals.

Moisten just enough to make loose-textured ball when squeezed, or crumbly mash when scooped without pressure. Since moist bran molds, mix only enough bait for one application. (Quantity given is enough for 5 acres.) Corn meal, rice flour, oatmeal, or wheat flour work less well than bran, but may be substituted if necessary. Sodium fluosilicate is the only poison which has been found effective in bait against the southern mole cricket. Scatter bait evenly; if possible, with a

few flakes on every square inch. Scatter at sundown or just before (mole-crickets are night feeders), when soil is moist. As sodium fluosilicate injures tender vegetation, the bait should not touch newly germinated seedlings. Treatment usually must be repeated a second, and sometimes a third or even a fourth time, at 10-day intervals.

For other controls see benzene hexachloride, chlordane, chlorinated camphene (Toxaphene), DDD, and DDT.

FUNGICIDES 51/

51/ The information on these, unless specifically credited to other sources, has been derived largely from (Amer. Assoc. Ec. Ent., 1947; Davis, Wright, and Hartley, 1942; and McCallan, 1948)(___, ___, ___), and from unpublished data of the Bureau of Plant Industry, Soils, and Agricultural Engineering, Region 8 of the U. S. Forest Service, and the Southern Forest Experiment Station.

Timely application is vital to success with fungicides, and frequently involves anticipation of fungus outbreaks and treatment before infection takes place. In contrast to insecticides, which often kill insects if applied promptly after their appearance, fungicides function principally by coating the plant with chemicals which kill the fungi when they first lodge on the surface, or at least keep them from invading the plant tissues. Once fungi are inside the plant, fungicides ordinarily cannot control them. (Horsfall, 1945; McCallan, 1948)(___, ___)

The spreaders and adhesives ("stickers") suggested for the following fungicides are either used regularly with them on southern pines or are commonly recommended for use with them on other plants. For more details, see p. 530.

Acetic acid, usually the commercial 80 percent concentration, is applied to seedbeds to control damping-off, either immediately after sowing or, preferably, 5 to 6 days before, at the rate of $\frac{1}{4}$- to $\frac{1}{2}$-fluid ounce per $1\frac{1}{2}$ to 2 pints of water per square foot (Hartley, 1935) (___). Although it has been little used on southern pines, it is reported to be less injurious than other acidifying substances, and deserves further trial where acidification is needed.

Bordeaux mixture (copper sulfate-lime mixture; blue stone-lime mixture), is used in the nursery for top damping-off, Thelephora, needle casts, brown spot on longleaf and other species, and southern fusiform rust on slash and loblolly (but see "Fermate" and Zerlate"). Occasionally it is used for brown spot on longleaf in plantations.

Bordeaux mixture in different concentrations can be made up from commercial powders or pastes; more varied concentrations of usually better quality can be prepared at home. Final mixtures should be applied immediately after preparation, as they are unstable and rapidly lose effectiveness.

Satisfactory home mixtures may be made either: (a) by combining previously prepared stock solutions of lime and of copper sulfate; or (b) by mixing high-grade copper sulfate and lime in a power sprayer equipped with an agitator, without first preparing stock solutions. Stock solutions may be stored for considerable periods and both copper sulfate and lime may be used in different forms and grades; mechanical agitation is not essential, and small quantities of the final mixture may be prepared at any time; but the method requires more labor and containers to handle the materials.

In either method, any desired strength may be prepared by altering the quantities of copper sulfate and lime. By substituting zinc sulfate for copper sulfate, zinc sulfate-lime solution may be prepared.

A. Stock solutions.--Make stock solution of copper sulfate by stirring and completely dissolving copper sulfate crystals, ground or unground, in water, at the rate of 1 pound of copper sulfate to 1 gallon of water. (This solution must be prepared and stored in earthenware, glass, or wood.) Unground crystals are most easily dissolved by weighing them out into a permeable cloth bag and suspending the bag with its lower half in the top of the water in the barrel; placing crystals in the bottom of the barrel slows the process greatly.

Make stock solution of lime by slaking and dissolving 1 pound of quicklime or dissolving $1\frac{1}{2}$ pound of hydrated lime per 1 gallon of water. If quicklime is used, add water slowly until the lime is thoroughly slaked, then add the rest and stir thoroughly. Hydrated lime must be of a quality and fineness to dissolve well, preferably that sold specifically for preparation of fungicides, or the "chemical" grade containing more than 70 percent calcium oxide and less than 2 percent magnesium oxide, and ground to pass a 300-mesh sieve. Hydrated lime dissolves more easily in cold water than in hot, and in soft water than in hard. Magnesium as an impurity in the lime decreases its solubility.

To prepare 4-4-50 Bordeaux mixture, combine stock solutions and water in the proportion of 4 gallons of copper sulfate solution, 4 gallons of lime solution, and 42 gallons of water. For a $2\frac{1}{2}$-3-50 mixture, combine in the proportion of $2\frac{1}{2}$, 3, and $44\frac{1}{2}$ gallons, respectively.

Stir each stock solution well before measuring out the quantity needed for the mixture. Do not mix the stock solutions directly. Instead, dilute the measured quantity of lime stock solution with about three-fourths of the extra water required, and dilute the measured copper sulfate stock solution with the remaining one-fourth of the extra water, stirring each solution while diluting. Then, stirring the diluted lime solution, pour the diluted copper sulfate solution into it. Add spreader or sticker after this final mixing has been completed. Apply immediately.

B. Mixing in sprayer.--Use only powdered or "snow" forms of copper sulfate, and only fresh supplies of hydrated lime, finely ground, of the special fungicidal or "chemical" grade.

To mix 100 gallons of 4-4-50 Bordeaux in the sprayer tank, make a fluid paste of 12 pounds of hydrated lime and a little water. Pour 25 gallons of water into the sprayer and start the agitator. Place 8 pounds of powdered copper sulfate crystals on tank-inlet screen, and wash it into the tank with about 50 gallons of water, keeping the agitator running. Then pour the lime paste through the screen into the tank, still agitating, and wash the last of the paste through with enough water to bring the total used to 100 gallons. Still agitating, add the spreader or sticker desired. Apply immediately.

The Bordeaux mixture commonly used is 4-4-50 (also called 8-8-100) --4 pounds of copper sulfate and 4 pounds of lime to 50 gallons of water, but $2\frac{1}{2}$-3-50 or 2-4-50 usually controls brown spot and is more economical. Bordeaux is naturally highly adhesive, but whale-oil, fish-oil, or resin-fish-oil soap (2 pounds per 50 gallons), or Santomerse S (3/8 to 1/2 pint per 50 gallons) is usually added as a spreader or sticker; raw linseed oil (5 quarts per 50 gallons) is used for particularly long-lasting effect. Direct injury by Bordeaux to conifers is practically unknown, and while there has been speculation about possible bad effects from accumulation of copper in the soil through long-continued use, such injury has not been proved in southern pine nurseries. Bordeaux mixture is corrosive to metals and must be thoroughly washed from spray equipment after use. (Hartley, 1935; Horsfall, 1945; Siggers, 1944)(___, ___, ___).

For top damping-off of southern pine nursery seedlings, spray with 4-4-50 Bordeaux as soon as trouble is identified with moderate certainty. From schedules developed for brown spot (Siggers, 1944) (___), a rate of 1 gallon per 100 to 250 square feet of seedbed is suggested.

It is better to try the treatment only on small areas on first suspicion of top damping-off, or spray all but a few small check plots saved for comparison, than to delay spraying until a pathologist positively identifies the disease.

For southern fusiform rust on slash, loblolly, and occasionally on longleaf pine, if Fermate or Zerlate is unavailable, spray with 4-4-50 Bordeaux (plus $\frac{1}{2}$ pint of Santomerse S per 50 gallons of mixture) at about 5 gallons per 1,000 square feet of actual nursery bed. This equals about 220 gallons per acre, net, of beds, or 145 gallons per acre of 4-foot beds and 2-foot paths, per spraying. Use enough pressure (preferably 275 to 325 pounds per square inch) to insure good coverage. The first treatment must be applied as soon as infectious conditions develop, even if it must be sprayed on burlap or straw mulch. If sowing is before March 15, apply first spray one week after the buds

on oaks nearby have burst, at the latest by the time the oak leaves are no larger than one half their mature size. Once started, spraying should continue weekly until the middle of June--ordinarily about 10 times per season. If wet weather upsets schedule, miss no opportunity to apply a spray any time it will dry on the foliage.

For brown spot on longleaf pine or other nursery stock, spray with 4-4-50, 2½-3-50, or 2-4-50 Bordeaux, as local tests may indicate, with 3/8 to ½ pint Santomerse S per 50 gallons, at rate of about 4 to 5 gallons per 1,000 square feet (net) of seedbed, at perhaps 125 to 300 pounds pressure. In nurseries in which brown spot is likely to be serious, spray first in June or late May, or when secondary needles first develop, even if no infection is visible; in any nursery, spray without fail when scattered brown-spot lesions appear. Repeat at intervals of 4 to 6 weeks or whenever abundant new foliage develops, and especially if infection increases; 4 to 7 sprayings are usually sufficient, ending in September or October. Rainy seasons or recurrent infections necessitate more frequent spraying than dry seasons or evident control Apply a final spray at same rate, but preferably with raw linseed oil as a sticker, a few days before lifting. (Siggers, 1944)(___)(unpublished data, U. S. Forest Service)

For brown spot on longleaf pine in plantations, spray with 4-4-50 Bordeaux plus suitable sticker, sufficiently to coat foliage, in May and November of two consecutive years--either the first and second years in the plantation, or the first and second after December infection of the foliage exceeds 12 to 15 percent. Amount of mixture required per acre will vary greatly with spacing, survival percent, and size of pines; pines more than 18 to 30 inches high need not be sprayed unless conspicuously infected (Siggers, 1944)(___)(unpublished data).

For needle cast in nursery or plantation, spray with double strength (8-8-50) Bordeaux, at 3 to 4 week intervals, from time needles are half grown (or when infection becomes evident) until needles are full grown. Spray sufficiently to wet foliage.

For Thelephora, 4-6-50 Bordeaux is recommended. Spray when fungus appears. Apply enough to wet the fruiting bodies.

Ceresan is one of the organic mercury fungicides applied as a dust to seed before sowing, as a protection against both seed-borne and soil-borne organisms. It contains, as the active ingredient, 5 percent of ethyl mercury phosphate. There is little information concerning its effectiveness with southern pines, but, applied at rates of ½ to 2 ounces per bushel or 2 to 8 ounces per 100 pounds of dry seed, or according to manufacturers' specifications, it may reduce pre-emergence damping-off. It is highly toxic to humans, and must be handled with care.

Chloropicrin is coming into increasing use to control soil fungi. Found effective against nematode-complicated "root rot" in one U. S. Forest Service nursery (Lindgren and Henry, 1949)(___).

Copper oxide (cuprous oxide), applied as a dust to seed before sowing, at the rate of 1 ounce per pound of dry seed, or according to manufacturers' directions, may reduce pre-emergence damping-off, but may cause chemical injury to the seedlings if sowing is in very hot weather.

Ethylene dibromide. Not considered a reliable fungicide, but found effective in one U. S. Forest Service nursery against nematode-complicated "root rot"; for details see p. 516 and also chloropicrin.

Fermate ("Karbam black"), ferric dimethyldithiocarbamate, a black, wettable powder, is apparently a good general fungicide; unusually effective for rust, for which it is superior to Bordeaux. It is compatible with most insecticides and fungicides, including summer oils and lead arsenate, but not with those containing copper, mercury, or lime in any form. (Wysong, 1948)(___).

For southern fusiform rust on slash, loblolly, and longleaf pines, apply 2 pounds of Fermate and 1 pint of Santomerse S in 100 gallons of water at the rate and schedule specified for Bordeaux for this disease. To mix, make a thin paste of Fermate and water, adding water a little at a time, together with a few drops of Santomerse S to speed up mixing; then pour paste and rest of water and Santomerse S into spray tank and complete mixing there. The process is easier than preparing Bordeaux.

Formaldehyde ("formalin") is applied to seedbeds and sometimes to germination-test sandflats before sowing to control damping-off. The strongest commercial solution available, usually about 40 percent, is diluted with water and applied at a rate to give $\frac{1}{4}$, $\frac{1}{2}$, and in extreme cases 2/3 fluid ounce of the 40 percent solution plus about 2 pints of water (or somewhat less if the soil is very wet) per square foot of bed; this dosage is followed immediately by heavy watering. The beds must be aired for 4 days to 3 weeks before sowing; the lighter the soil, the lower the humus content, and the lower the temperature, the longer the period of airing required. Covering the beds with paper or burlap for 3 to 5 days between treatment and airing is not necessary. The soil must not be turned over or stirred deeply between treatment and sowing--even "freshening" of the surface by raking should be kept to a minimum-- and no soil covering except formaldehyde-treated soil or clean quartz sand should be applied over the seed. This treatment is expensive, but generally effective; with proper airing it leaves no residue to injure germinating seeds, and is safe to use on any soil, regardless of pH concentration or past treatments (Hartley, 1935)(___).

For sand-flat germination tests, saturate the sand in the flats with 40 percent formaldehyde solution diluted at the rate of $\frac{1}{2}$ fluid ounce to 2 pints of water, in time to permit thorough airing before seeds are set.

Lime-sulfur is used less generally than Bordeaux mixture for brown spot on longleaf seedlings because it is incompatible with many other sprays and may also injure the plants in hot weather. It may be substituted for Bordeaux, if the latter is unavailable, at the rate specified for Bordeaux 4-4-50, and in the dosages noted on p. 518.

Methyl bromide, applied to seedbeds, in dosages like those recommended on p. 517, or, before sowing, in higher dosages as recommended by manufacturers, may effectively control damping-off and other soil-borne diseases.

Semesan is a hydroxi-mercuri-chlorophenol dust, applied dry or in water solution to seed, before sowing, to control seed-borne diseases and damping-off. It is possibly useful in this way to control preemergence damping-off of southern pines. It is occasionally sprayed on nursery seedlings to control top damping-off, including sand-splash of longleaf pine. Highly toxic to humans; handle with utmost precaution. For top damping-off in general, apply in water according to manufacturers' directions, at rate of 1 gallon of solution per 100 square feet. For sand-splash of longleaf, apply 1/10 ounce of Semesan per 1 pint of water per square foot of seedbed on, and 1 to $1\frac{1}{2}$ foot around all patches obviously attacked. In either case, treat only in late afternoon or on cloudy days with no likelihood of clearing, as mid-day treatment on sunny days is likely to injure the plants.

Sulfur is available as a dust (in this form it should pass a 325-mesh screen), and in "modified" forms--paste or wettable powders (Colloidal sulfur, Kolofog, Magnetic 70, Micronized, Micro spray, Mike, Mulsoid, and the like), many of which are adapted to preparation of lime sulfur. Sulfur in any form is incompatible with many oil sprays. It has been little used for diseases of southern pines, but colloidal sulfur is easy to mix and apply according to manufacturers' directions, and has given good control of brown spot on longleaf pine.

Zerlate (Methosan, Karbam white) is zinc dimethyldithiocarbamate, a white, wettable powder readily suspended in water. Like Fermate, it is apparently a good general fungicide, and superior to Bordeaux for rusts. It is used at a rate of $1\frac{1}{2}$ to 2 pounds per 100 gallons of water. For southern fusiform rust in nursery seedbeds, prepare like Fermate and apply at rate and according to schedule given for Bordeaux. (Wysong, 1948)(___).

Zinc sulfate - lime is identical with Bordeaux mixture except that zinc sulfate is substituted in equal quantity for copper sulfate for the particular strength or proportion of mixture desired. It may be used when for any reason copper must be avoided or when copper sulfate is unavailable. Prepare like home-made Bordeaux mixture, except that the zinc sulfate may be dissolved in water without using the suspended bag required for copper sulfate; apply like Bordeaux mixture. Has proved reasonably effective for brown spot on longleaf pine.

SPREADERS AND STICKERS 52/

52/ Most of the information concerning these, unless otherwise noted, is from (Davis, Wright, and Hartley, 1942)(___) and unpublished data of the Bureau of Plant Industry, Soils, and Agricultural Engineering.

Directions for spraying southern pines often call for a spreader or sticker without specifying what kind, or even distinguishing between the two. Choice of the correct spreader or sticker frequently is more important than such vague directions imply. Omitting one or the other may result in incomplete or too brief coverage by either insecticides or fungicides. Choosing the wrong spreader or sticker may nullify the chemical effect of the spray.

Spreaders are necessary with many contact insecticides, and stickers with some stomach poisons and fungicides. In general, spreaders--substances that promote wetting--are not good stickers; they reduce the original deposit when applied, and reduce its later durability. They are advantageous with contact insecticides primarily, because such insecticides depend for effectiveness upon wetting the insects, not upon adhering to the leaves. Most soaps are good spreaders but poor stickers, and particularly poor with arsenicals. Many soaps and other spreaders are useful in emulsifying oils, and most soaps and most alkaline spreaders increase the effectiveness of nicotine sulfate for aphids, red spider, and scale insects, by reacting chemically with the nicotine sulfate as well as by improving wetting. Petroleum oils differ from soaps in being good stickers as well as spreaders, and certain animal oils (including fish oil) and vegetable oils are excellent adhesives. Calcium caseinate is chiefly a sticker, but acts to some extent as a spreader also. (Amer. Assoc. Econ. Ent., 1947; Gwinner, 1946; Horsfall, 1945)(___, ___, ___)

Many published spray-recommendations include "soap" as a spreader, without specifying what kind, or specify one kind without regard to differences in conditions under which it may have to be used. Such recommendations may be undependable because of differences among soap--water contents varying from 8 to 70 percent, for example, and differences in jelling properties and in reaction to different temperatures (Gwinner, 1946)(___).

Horsfall, although granting that oils, especially glyceride drying oils, are excellent stickers, deprecates the use of stickers and especially of spreaders. He points out that Bordeaux mixture is naturally highly adhesive; that the inclusion of soap in a spray to make it cover the surface better also makes the spray more likely to

run off before drying and to wash off in rains after it has dried; that calcium caseinate, widely popular in the 1920's "has largely gone out because no one could demonstrate that it paid its way"; and that calcium caseinate and other proteinaceous colloids, although tenacious, have frequently interfered with the fungicidal action of the spray toxicants (Horsfall, 1945)(___). It is noteworthy in this connection that few, if any, recommendations concerning either spreaders or stickers accompany specifications for treatment with the insecticides developed since World War II.

In contrast to Horsfall, Davis and co-workers say that "Spreaders or adhesives must be used if good results are to be obtained with fungicides on conifers" (Davis, Wright, and Hartley, 1942)(___). This statement is borne out to some extent by difficulty in getting even the naturally adhesive Bordeaux mixture to stick to pine seedlings in the cotyledon and early primary-needle stages, when spraying for fusiform rust. For such spraying, Santomerse S, a commercially available salt of substituted aromatic sulfonic acid in aqueous solution, has proved a satisfactory sticker with Bordeaux, Fermate, and Zerlate.

<u>Casein spreader</u> (calcium caseinate; casein-soap; "Kayso") may differ considerably in efficiency from lot to lot. In general, calcium caseinate or any preparation of which it is an ingredient should not be used with any insecticide or fungicide noted as being incompatible with <u>lime</u>, or oil spreaders or stickers with those noted for being injurious in combination with oils. Calcium caseinate has been largely superseded by other stickers.

<u>Raw linseed oil</u> (boiled linseed oil is not recommended) is perhaps the most lasting sticker so far employed on southern pines, but is also among the most expensive, requires emulsification before use, and is extremely difficult to remove from sprayers, requiring prompt use of white gasoline for this purpose. It may injure foliage, but such injury to southern pines appears to have been negligible. Used with Bordeaux mixture, linseed oil may be emulsified by simply pouring the oil into the Bordeaux and pumping the two through the spray nozzle back into the tank. Used with other fungicides, linseed oil may have to be emulsified before mixing by agitating violently 6 pounds of the oil, 6 pounds of fish-oil soap, and 6 gallons of water (6-6-6 emulsion). An emulsion of linseed oil and fish-oil soap is nearly as good a sticker as straight linseed oil, and both have given better results than Santomerse in limited tests of trees sprayed in the plantation (pp. 290 and 343). Linseed oil has been used as a sticker mostly for Bordeaux mixture applied to longleaf pine nursery seedlings at lifting time to reduce brown-spot infection after planting, and for Bordeaux mixture applied semiannually to planted longleaf pine; under these conditions the lasting-quality of linseed oil at least partly offsets its cost.

<u>"Santomerse".</u> A spreader and sticker available in two forms, D, a powder, and S, a liquid. The latter has been widely used on southern pines, with good effect, in combination with Fermate and Zerlate as well

as with Bordeaux mixture. It is one of the most effective stickers for spraying nursery seedlings in the cotyledon and early primary-needle stages to control fusiform rust.

Table 30 is a general guide to quantities of spreaders or stickers to use. Wherever more specific directions are given in connection with particular insects, diseases, insecticides, or fungicides, they should be followed.

Table 30.--Quantities of spreaders and stickers commonly used with sprays on southern pines

Spreader or sticker	Spray with which used on southern pine 1/	Quantity recommended per 100 gallons of spray 1/	
		Usual	Range
Calcium caseinate or casein spreader (Kayso)	Bordeaux	4 lbs.	4 to 8 lbs.
Fish oil soap	Bordeaux	4 lbs.	...
Linseed oil (raw)	Bordeaux	10 qts.	4 to 15 qts.
Linseed oil-fish oil soap emulsion	Bordeaux and others	5 qts.	4 to 9 qts.
Ortho-spreader	Lime sulfur	2 lbs.	...
Resin-fish oil soap	General	4 lbs.	...
Rosin-residue emulsion (HCL sticker)	Bordeaux	1 pt.	...
Santomerse D	Bordeaux	4 ozs.	...
Santomerse S	Bordeaux, Fermate, and Zerlate	1 pt.	1/8 to 1 pt.
Silmo (Spread-ol)	Bordeaux	1 pt.	...
Soap	Lubricating-oil emulsion	$14\frac{1}{2}$ lbs.	...
	Nicotine sulfate	...	2 oz. to 3 lbs.
Whale oil soap	Bordeaux	4 lbs. or 2 qts.	...

1/ As recorded in literature and unpublished data cited for insecticides, fungicides, and spreaders and stickers.

MISCELLANEOUS BAITS, REPELLENTS, AND COATINGS

All the poisons in the baits described here are dangerous, and must be used with the precautions detailed on page 508. Use cover over baits on ground, or place bait in underground burrows or in places inaccessible except to mice or other harmful rodents.

Mouse Baits

1. For meadow and pine mice (Garlough and Spencer, 1944)(___).

Steam-rolled oats	98 lbs.
Amber petroleum jelly	10 ozs.
Mineral oil	10 ozs.
Zinc phosphide	1 lb.

Warm the mineral oil and the petroleum jelly together until fluid but not hot. Add zinc phosphide and stir briskly to suspend. Pour suspension over the oats in open box or mechanical mixer and mix until the grains are evenly coated. The bait, which will keep for some time, need not be dried before sacking or use.

2. For field or white-footed mice (Fla. Dept. Agr., 1938)(___).

Powdered strychnine alkaloid 53/	1 oz.
Baking soda	1 oz.
Rolled oats	8 - 10 qts.
Beef fat	1 qt.

53/ Not strychnine sulfate, which is much less effective (Fla. Dept. Agr., 1938)(___).

Mix the strychnine and soda together and sift uniformly over oats, stirring well; warm oats in oven, but do not scorch. Sprinkle heated beef fat over oats and stir till oats are uniformly coated. Use fresh, placing 1 teaspoonful in the middle of each 20 by 20 foot square; above quantity treats about 4 acres.

3. For white-footed mice (Garlough and Spencer, 1944)(___).

Steam-rolled oat groats	125 lbs.
Thallium sulfate	1¼ lbs.
Water	1 gal.
Dry gloss starch	½ lb.
Glycerine or petrolatum	3/8 pt.

Dissolve the thallium sulfate in 3½ quarts of boiling water. Mix the starch with 1 pint of cold water, stir mixture into thallium solution, and cook until a clear paste is formed. Add the glycerine or petrolatum--though this may be omitted if bait is to be used immediately. Pour the mixture over the oat groats and mix until grains are uniformly coated. Use only enameled or wooden utensils; distribute with spoon or special dipper. Use on direct-seeding areas, either alone or 10 to 20 days after a preliminary strychnine bait (formula 2), placing 1 teaspoonful in the middle of each 20 by 20 foot square.

Always cover each bait with a piece of bark, a chip, or other cover under which mice and only mice ordinarily run.

Never touch or handle thallium baits with the bare hands.

4. For house mice (also pocket gophers)(Garlough and Spencer, 1944)(___).

Milo maize	6 lbs.
Thallium sulfate	1 oz.
Water	9 fluid ozs.
Gloss starch	1 tablespoonful
Heavy corn syrup	1 fluid oz.

Dissolve the thallium sulfate in 7 ounces boiling water. Mix starch with 2 ounces cold water, add syrup, and stir into boiling thallium solution. Cook until mixture begins to thicken, then pour over milo maize and mix until grains are evenly coated. Spread out to dry before using or sacking. Never touch thallium baits with the bare hands.

Pocket Gopher Baits

1. Cut carrots or sweet potatoes into pieces ½ by ½ by 1½ inches. Over 2 quarts of pieces sift 1/8 oz. of powdered strychnine alkaloid (not strychnine sulfate), stirring while sifting.

2. Mix 3/4 pint cold water and 2/5 ounce laundry starch; bring to a boil, stirring constantly; cook to a smooth paste. Then stir into the paste ¼ pint corn syrup, followed by ½ ounce glycerine.

Then mix, dry, in a 1-gallon container:

1 ounce powdered strychnine alkaloid
1 ounce baking soda

Pour the hot paste over the dry mixture, stirring thoroughly while pouring.

Pour the whole mixture over 16 quarts of plump wheat kernels or steam-rolled oats. Stir till the kernels are well coated; then spread out until dry.

3. See mouse bait no. 4 (milo maize).

Rabbit-repellent Spray

A rabbit-repellent spray may be applied to slash, loblolly, or shortleaf pine seedlings a few days before lifting, by means of a straddle-bed sprayer equipped either with a 1-bed roller preceding a regular 1-bed spray boom, or with a similar roller and an extension hose and hand-nozzle operated by a man following the sprayer on foot. The roller is adjusted to bend the seedlings gently as the spray hits them, to insure coverage of the vulnerable portions of the stem just above the root collar. With the bar and boom combination, the sprayer should pass over the bed twice, from opposite directions.

Copper carbonate-asphalt emulsion mixture.--Mix 3 lbs. asphalt emulsion and 2 quarts of water; add 2 lbs. copper carbonate and mix; dilute with 8 additional quarts of water, and mix. Apply at rate of ½ pint to 3 pints per 1,000 trees.

For additional effective sprays, and for lists of sprays found ineffective against rabbits or injurious to trees, see (Cardinell and Hayne, 1947; Garlough, Welch, and Spencer, 1942)(___, ___).

Foliage Coatings to Reduce Transpiration

1. Lanolin emulsion

Lanolin (anhydrous Adeps Lanae)	100 grams
Monoethanolamine stearate	10 grams
Water	1 liter

2. Dowax

Commercial Dowax emulsion	1 part by weight
Water	3 parts by weight

In Marshall and Maki's tests, (Marshall and Maki, 1946)(___), the seedling tops were dipped in one or the other of these coating-materials, but either material may also be sprayed.

PLANT QUARANTINE AND NURSERY INSPECTION OFFICIALS
(Amer. Assoc. Ec. Ent., 1949)(___)

Alabama	Chief, Division of Plant Industry, Montgomery 1
Arkansas	Chief Inspector, State Plant Board, Little Rock
Delaware	State Board of Agriculture, Newark
Florida	Plant Commissioner, State Plant Board, Gainesville
Georgia	Director of Entomology, State Capitol, Atlanta 3
Illinois	Inspection Supervisor, 300 State Bank Building, Glen Ellyn
Indiana	State Entomologist, Indianapolis
Louisiana	State Entomologist, Capitol Station, Baton Rouge
Maryland	State Entomologist, College Park State Plant Pathologist, College Park
Mississippi	Executive Officer, State Plant Board, State College
Missouri	State Entomologist, Department of Agriculture, Jefferson City
New Jersey	Chief, Bureau of Plant Industry, Trenton 8
North Carolina	State Entomologist, Department of Agriculture, Raleigh
Ohio	Division of Plant Industry, Department of Agriculture, Columbus
Oklahoma	State Board of Agriculture, Oklahoma City 5
Pennsylvania	Director, Bureau of Plant Industry, Harrisburg
South Carolina	Crop Pest Commission, Clemson College
Tennessee	State Entomologist, University of Tennessee, Knoxville
Texas	Chief, Division of Plant Quarantines, Department of Agriculture, Austin
Virginia	State Entomologist, 1112 State Office Building, Richmond 19

WIRE SCREENS TO PROTECT SEED SPOTS

A pattern (Miller, 1940)(___), cut to the dimensions shown in fig. 49, makes a cone standing about 5 inches high with a basal diameter of about 4.5 inches at the soil surface, when the wire is set to a maximum depth of 2 inches. Cones may be of 1/2-, 1/3-, or 1/4-inch hardware cloth, or 1/16-inch mesh screen wire. The dimensions permit cutting 36-inch wire into 5 strips or 30-inch wire into 4 strips. Waste is negligible.

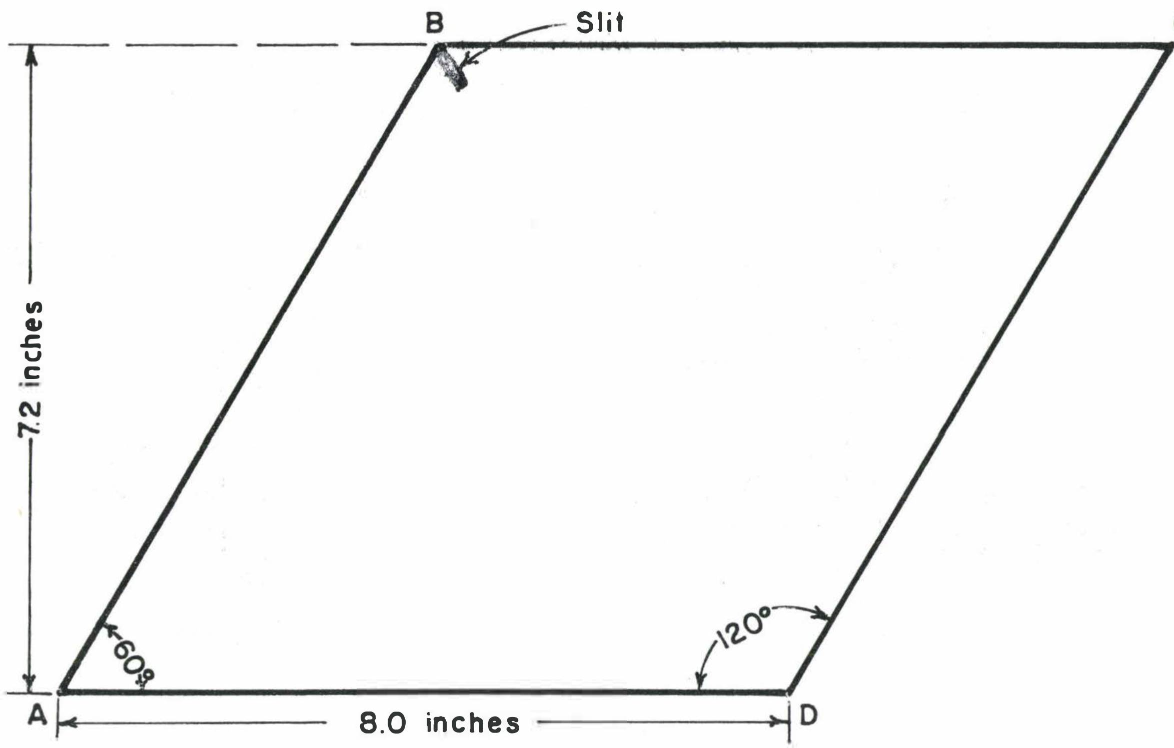


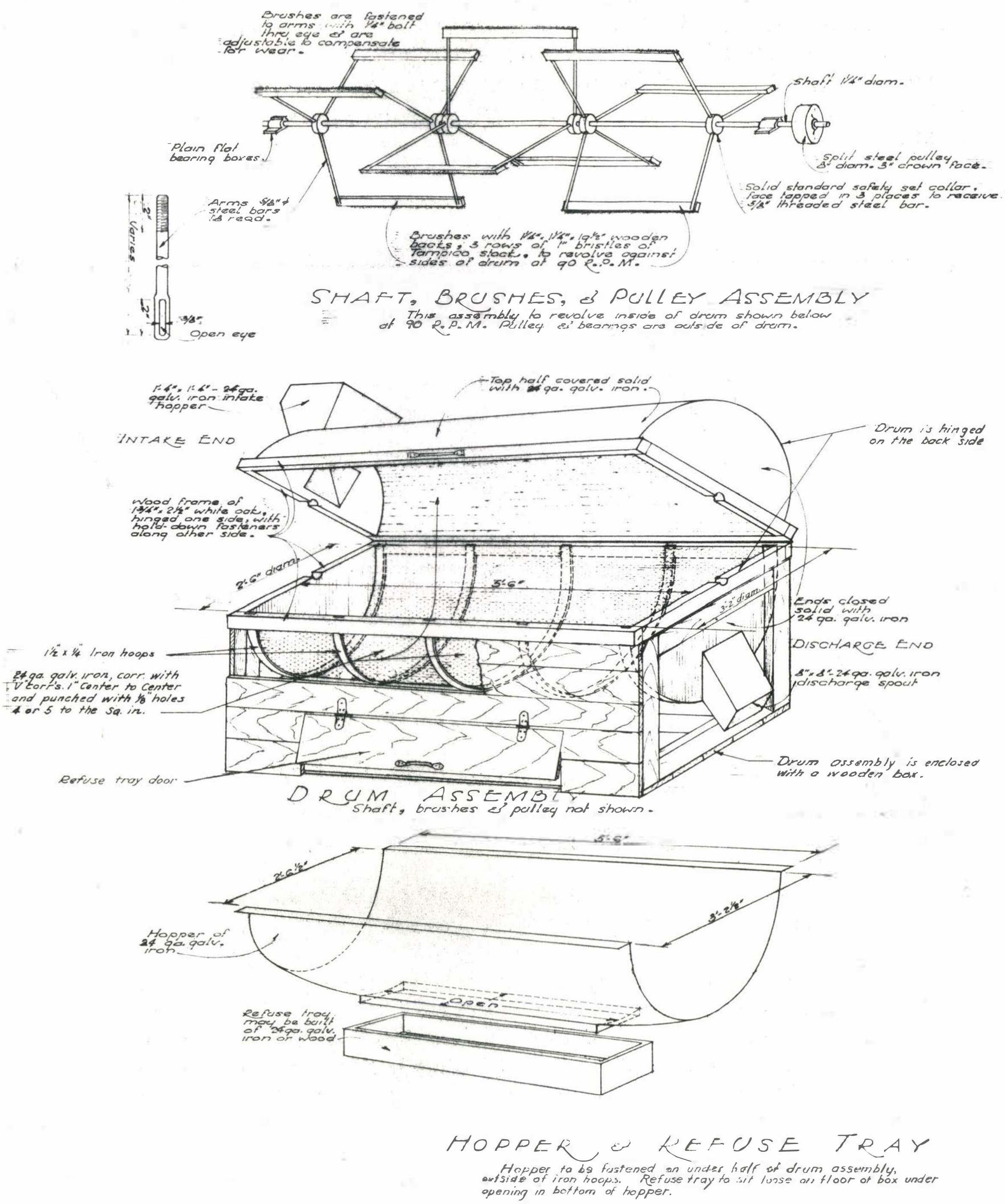
Figure 49.--Pattern for hardware-cloth or screen-wire cone to protect seed sown in prepared spot (Miller, 1940)(___).

In shaping the cone, the wire is rolled to bring edges AB and BC together. The slit at B facilitates lapping the edges, which are then wired or stapled together. For quantity production the wire cones may be rolled by means of a fixed or revolving wooden cone of appropriate taper, with a groove 8 inches long and ½ inch deep running down from its apex to take edge AB of the wire. The finished cones nest conveniently.

When the cone is installed, corner D and corners A and C (joined) project somewhat deeper into the soil than the middles of sides CD and DA.

Domes made from hardware cloth disks (Garlough and Spencer, 1944; Keyes and Smith, 1943)(___, ___) appear less economical than the cones.

FIGURE 50.--DETAILED CONSTRUCTION OF PINE SEED DEWINGER USED BY REGION 8, U. S. FOREST SERVICE.



SEED-SAMPLING PROBES

A grain trier or probe satisfactorily draws 100-seed or larger samples of southern pine seed, except longleaf, from sacks or cans. The probe consists of two slotted tubes, one turning inside the other to close the slots or to open them and admit seed into the inner tube. For most purposes a 30-inch by $\frac{1}{2}$-inch probe is convenient; if it draws too large a sample of a small-seeded species, patches can be taped or soldered over some of the slots. Agricultural supply dealers usually can supply probes or tell where to get them.

Longleaf seed, because of the persistent wings, needs a special probe about $2\frac{1}{2}$ inches in diameter. One practical homemade form consists of a long outer cylinder of galvanized iron heavy enough to resist easy denting. This outer cylinder is closed at both ends, with the lower end finished in a blunt point. Inside the lower end is a shorter cylinder, closed at its upper end only, and rotated by means of a $\frac{1}{4}$-inch iron rod projecting through the upper end of the long cylinder (fig. 51). Gates in the outer and inner cylinders are turned opposite each other to admit a sample of seed.

A probe with the dimensions shown in figure 51 draws a sample of about 100 longleaf seeds with wings attached. For drawing samples of 100 seed with wings reduced to stubs, it may be made with shorter gates, or the inner cylinder may be shortened with pieces of cork cemented into place.

Figure 51.--Special probe for sampling longleaf pine seed.

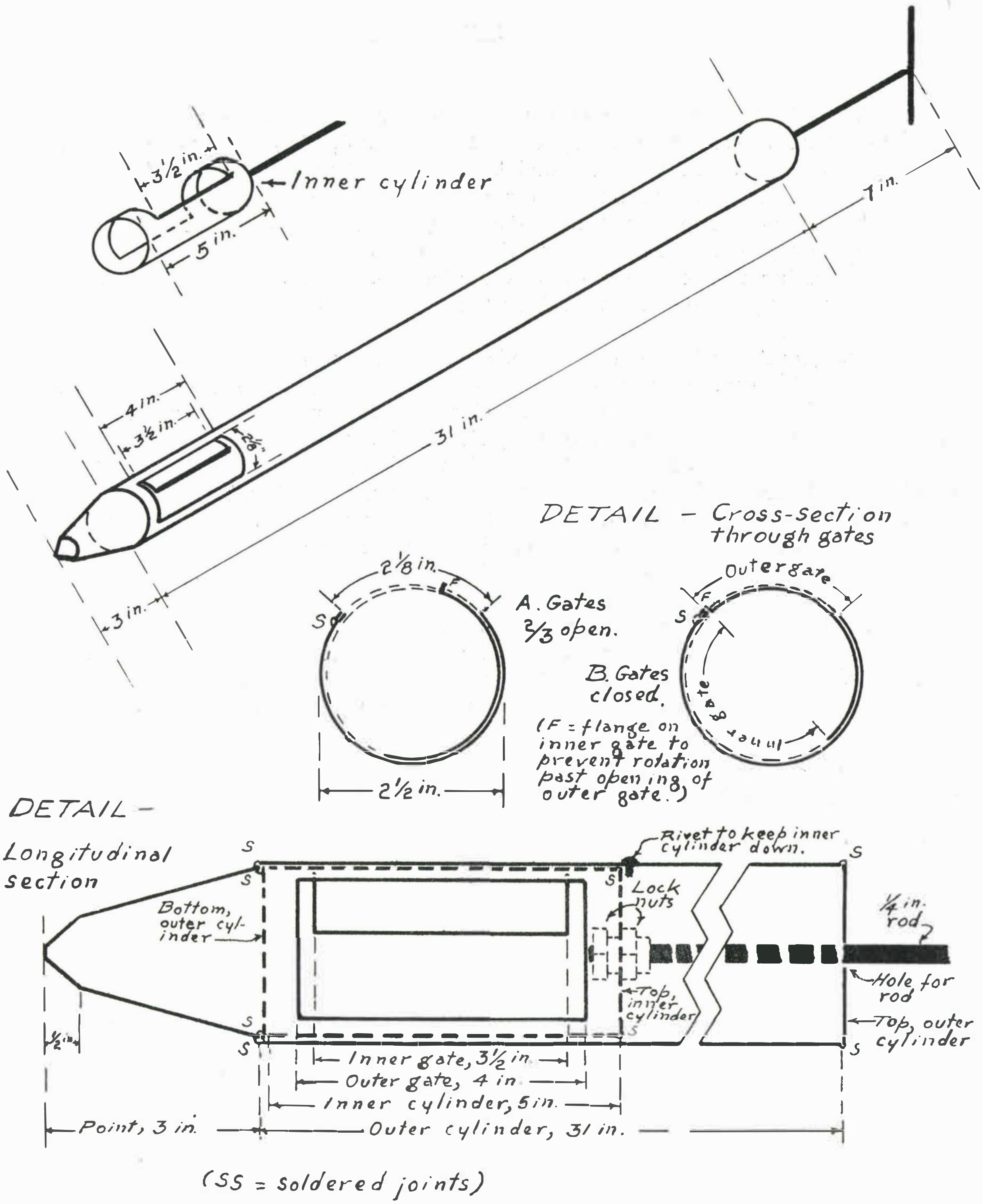


Figure 51.--Special probe for sampling longleaf pine seed.

GUIDE TO DRYING OF SEED

Fig. 52 permits direct reading of the net weight to which a lot of seed of known moisture content percent (oven-dry basis) and known net weight at time of sampling must be dried to reduce it to a specified moisture content percent.

Figure 52.--Guide to drying of seed.

For seed lots weighing less than 10 pounds, one decimal place may be pointed off in all values in the left-hand and right-hand vertical scales. For seed lots weighing more than 100 pounds, the desired weight may be totalled from readings for successive lots of 100 pounds each, plus a final lot of less than 100, or else all values in both vertical scales may be multiplied by 10.

To use the chart, find the point on the right-hand scale corresponding to the net weight of the seed lot when the moisture-content samples were drawn. Lay a straightedge across this point on the right-hand scale and the point on the center scale corresponding to the moisture content percent determined from the sample. Note the point of intersection of the straightedge with the left-hand scale.

Now lay the straightedge across this intersection point on the left-hand scale and across the point on the center scale corresponding to the moisture content percent to which the seed is to be dried. The reading where the straightedge intersects the right-hand scale is the net weight to which the seed lot must be dried.

Example.--A lot of slash pine seed weighed 243 pounds net when sampled for moisture content. The moisture content proved to be 17 percent. To what net weight must the lot be dried to reduce its moisture content to 8 percent? Solution: Straight-edge from 100 on right-hand scale through 17 on center scale gives 85 on left-hand scale. Straight edge from 85 (left) through 8 (the desired moisture content) on center scale gives 92 on right-hand scale. This is the weight to which the first and the second 100 pounds of the 243 must be dried. In like manner the last 43 pounds must be dried to 40 pounds, making 92 plus 92 plus 40, or 224 pounds, the net weight to which the 243-pound lot at 17 percent must be dried to reduce its moisture content to 8 percent.

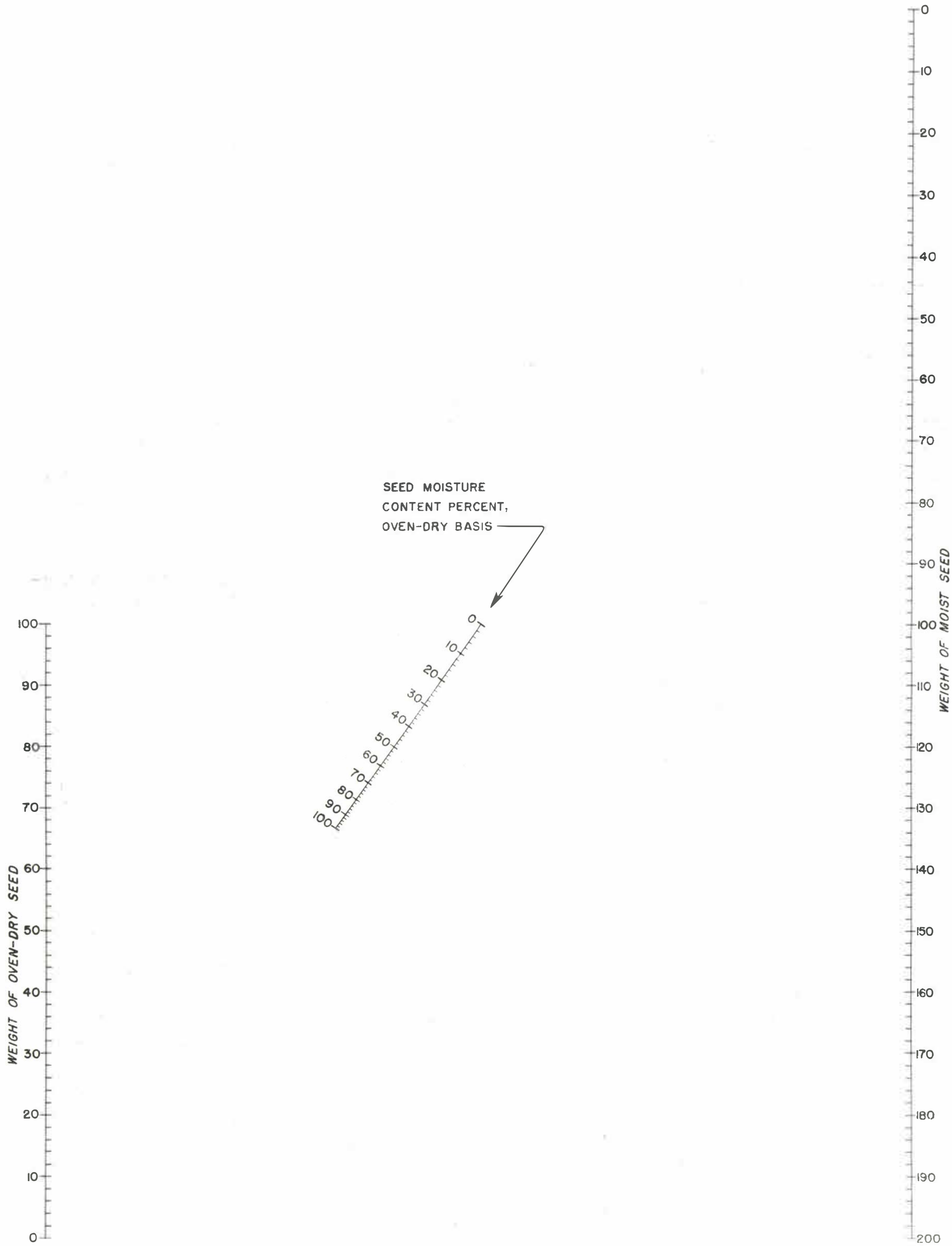


Figure 52.--Guide to drying of seed.

DIRECTIONS FOR GERMINATION TESTS

A. Facilities, Material, and Apparatus

1. Ample table and floor space (where sand, if used, and water will do no harm) for setting and conducting tests; an adequately lighted room with temperatures suggested in table 15, and, for sand flats, with a relatively moist atmosphere (to prevent too rapid drying of sand), for running tests after they have been set up.

2. Some device for measuring maximum and minimum temperatures daily throughout course of tests--a Sixe's maximum-minimum thermometer (and magnet) if a recording thermograph is unavailable.

3. Supply of water-resistant cardboard or roughened, opaque plastic tags (and thumb tacks for sand flats) for permanently labeling each subsample and marking boundaries between subsamples.

4. Small tweezers, with rounded rather than very sharp points, for pulling germinated seeds.

5. A supply of forms for recording germination, preferably a separate form for each 800-seed sample. The simplest, perhaps, is a letter-sized form like that on p. 544.

6. Numerous envelopes and small trays for seed samples.

(Items 7 through 17 are required only for sand-flat tests)

7. Clean quartz sand, fairly uniform in texture, and free from harmful fungi, from organic matter, and from substances that will cause the surface to cake when dry. Suitable sand usually can be obtained from sand bars along small streams or lakes, sometimes from well borings. Sea sand must be washed thoroughly to free it from salt. Regardless of source, the sand must be fine enough to hold water well. It should be sifted through 1/16-inch mesh wire. Dry samples should not appear finer than the grit on No. 0 sandpaper or coarser than that on No. $1\frac{1}{2}$; sand closely matching No. $\frac{1}{2}$ or No. 1 should be about right.

8. Platform scales (about 150 pounds capacity) to weigh full and empty containers of sand and of water.

Temperatures during test — Species: ____________

Maximum: ____________ Minimum: ____________ — Lot No.: ____________

Usual range: ______________________________ — Date set: ____________

Notes: ______________________________ — Tested by: ____________

a. Germinated normally on:-		Subsample								Average for all subsamples
		A	B	C	D	E	F	G	H	
Month and day	Day since start of test	- - - - - Percent 1/ - - - - -								
b. Germinated abnormally										
c. Ungerminated, sound										
d. Ungerminated, spoiled										
e. Ungerminated, empty										
Total, last line of a, plus b, c, d, and e										

1/ If, and only if, 100-seed subsamples are used, the percentages will be identical with the numbers of seeds observed.

9. Ample containers for sand and water; two tight wooden boxes, two galvanized iron wash tubs, and one 12-quart pail are about the minimum. Include shovels, scoops, or trowels for handling sand.

10. Four sand flats per sample of longleaf seed, and two flats per sample of each other species; flats of wood, $10\frac{1}{2}$ by $10\frac{1}{2}$ by $3\frac{1}{2}$ inches inside, with smooth edges to permit leveling sand with straightedge, and no cracks through which dry or over-wet sand may escape.

11. One mouse-proof screen-wire cover per flat, folded from about $13\frac{1}{2}$ by $13\frac{1}{2}$ square of 1/16-inch mesh, preferably aluminum screen wire.

12. One scraper of heavy galvanized sheet iron, cut to pattern shown in fig. 53. The projecting edges EE and E'E' must be exactly 10 3/8 inches long if flats are exactly $10\frac{1}{2}$ inches square, so that they will fit closely but freely inside flat when shoulders SS or S'S' rest on edges of flat. Edge EE is for setting longleaf seed; edge E'E' for other southern pines.

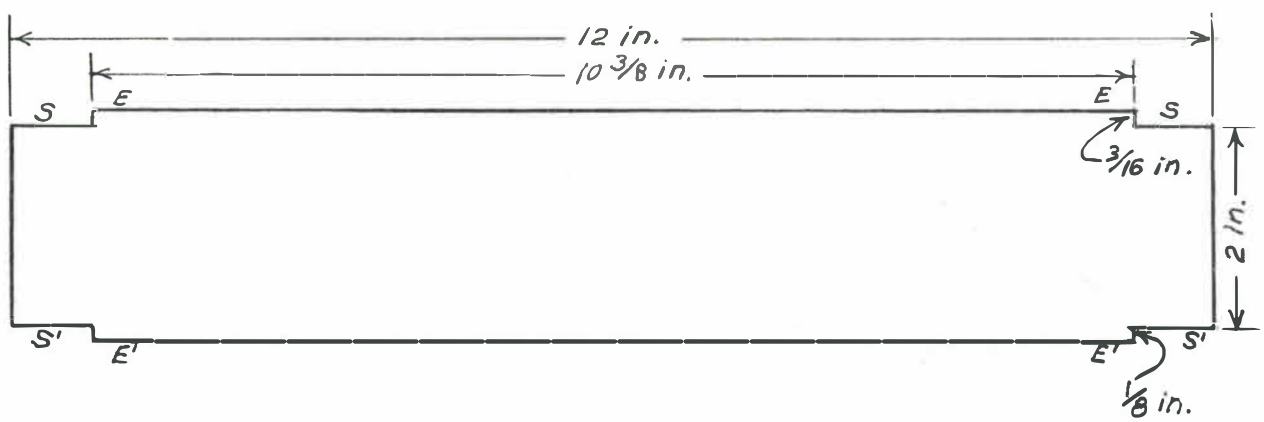


Figure 53.--Pattern for heavy galvanized iron scraper used in setting sand-flat germination tests.

13. Temporary partitions for dividing the surface of the sand in each flat into halves (in setting up 100-seed subsamples of longleaf seed) or quarters (for 100-seed subsamples of other species), with 1-inch clearances between subsamples. For longleaf a 1- by 1- by 10 7/16-inch wooden strip will do; for other species, two such strips cross-lapped together at right angles at their midpoints so as to lie flat on the sand.

14. Light tamps to insure that all seeds lie flat. Pieces of plywood 4 5/8 by 10 3/8 inches (for longleaf) and 4 5/8 by 4 5/8 inches (for other species), each with a knob in the center of one surface (for ease in handling), are convenient, or the seeds may be tamped a few at a time with a safety match box.

15. Bright crayon or soft black pencil for marking edges of flats.

16. A metal-edged 12-inch ruler or similar straightedge.

17. A sprayer (obtainable from florists' supply houses) fine enough to wet sand over seeds without displacing it. The ordinary watering-can nozzle is too coarse.

(Items 18 through 26 are required only for peat mat tests)

18. Glass dishes of suitable size, in which to place the peat mats. The $10\frac{1}{2}$- by $6\frac{1}{4}$- by 3/4-inch mat is designed to fit baking dishes 12 3/4 by 8 3/16 inches (outside top dimensions) by 1 7/8 inches high outside (1 5/8 inches deep inside), with slightly sloping sides. Dishes without end handles take less table space. Regardless of species of seed, a test of an 800-seed sample takes 4 dishes.

19. One cover-glass per dish, cut to project $\frac{1}{4}$ inch beyond top of dish all around; of extra-heavy window glass, <u>with edges and corners ground smooth to prevent cutting of hands during use.</u> Extra cover-glasses should be kept on hand to allow for breakage.

20. Granulated moss peat (florists' peat; acid peat moss), obtainable in bales from florists' or nurserymen's supply houses. It should consist primarily of particles derived from sphagnum moss, be reasonably free from rootlets and other coarse material, and be acid in reaction to promote normal germination of pine seeds and minimize development of mold.

21. A water-tight vessel, preferably a small wooden tub, for moistening a cubic foot or more of peat at one time. (The acid peat rapidly removes the coating from galvanized vessels.)

22. Strips of 1/16-inch mesh aluminum screen wire, 3/4 inch wide, cut from a 36-inch width, for peat-mat collars. (Galvanized wire will do, but because of deterioration in contact with the peat, cannot be reused for more than 1 or 2 successive tests.)

23. Moderately fine copper wire, on spools, for crossbraces on collars.

24. A strip of sheet aluminum or zinc $9\frac{1}{2}$ by 2 inches, with $\frac{1}{4}$ inch of one long edge turned up at angle of 60°, for placing seeds on mat.

25. Pitcher, beaker, or other vessel with spout, for watering mats.

26. A peat-mat mold and frame, made as follows:

Of 1-inch board, make a base for the mold, rectangular, 10 by 14 inches, including end-cleats to prevent warping (see fig. 54 A and C for cleats).

Drive four 4-penny nails vertically into this base to form the corners of a rectangle $10\frac{1}{2}$ by $6\frac{1}{4}$ inches, centered on the board. Measure the $10\frac{1}{2}$ and $6\frac{1}{4}$ inches to the outsides of the nails; for convenience in construction, pencil this $10\frac{1}{2}$ by $6\frac{1}{4}$ inch rectangle on the board. Cut the heads off the nails, leaving exactly 3/4 inch of each nail projecting above the board; file off any roughness on the nails; bend each nail very slightly toward the center of the board.

Now draw 9 parallel lines, 5/8 inch apart, lengthwise of the $10\frac{1}{2}$ by $6\frac{1}{4}$-inch rectangle on the board, dividing the rectangle into 10 exactly equal parts.

On each of these 9 lines except the middle one, fasten with fine brads a triangular wooden strip, so that its ridge or apex lies directly over the pencil line (fig. 54 A and C). Each strip is $9\frac{1}{2}$ inches long; its ends lie $\frac{1}{2}$ inch inside the ends of the $10\frac{1}{2}$ by $6\frac{1}{4}$ inch rectangle. The surface of the strip in contact with the board is $\frac{1}{4}$ inch wide. The ridge or apex of the strip is 3/16 inch above the board.

Smooth the strips and the exposed surface of the board between them with steel wool or fine sandpaper, warm the board, and pour over it a thin coating of melted paraffin. This coating, which must be renewed from time to time, keeps the peat from sticking to the mold.

Make the frame of four 2-inch strips exactly 3/4 inch thick, half-lapped at the corners to lie flat on the mold (fig. 54 B). Thickness of exactly 3/4 inch is important, as it determines the thickness of the finished peat mat. The inner opening of the frame should be just enough larger than $10\frac{1}{2}$ by $6\frac{1}{4}$ inches to let the frame fit easily but not loosely over the 4 nails in the mold when the nails are surrounded

by the screen-wire collar (fig. 54 A) used in making the mat. The easiest way to make the frame the right size is to mark and cut the pieces and fit them together around a collar in place on the nails.

B. Preparing Sand Flats

1. Weigh a suitable quantity of dry sand.

2. To this sand add 15 percent of water by weight, and mix until sand is uniformly moist throughout.

3. Fill each flat heaping full of moist sand, and drop it twice for distance of 6 inches onto solid table or floor to settle the sand. Pack all the sand within $1\frac{1}{2}$ inches of each corner lightly with the fingers as further safeguard against settling during later watering; fill resulting finger marks with moist sand.

4. If formaldehyde sterilization is necessary, strike off excess moist sand level with edges of sand flat, by means of straightedge, and apply formaldehyde as specified on p. 528; at same time, soak with formaldehyde a thin layer of sand spread on heavy paper, and allow to dry for use in step C-6.

5. With appropriate edge of scraper (fig. 53), remove excess moist sand, leaving level surface 3/16 inch (for longleaf) or 1/8 inch (for other southern pines) below top of sand flat.

C. Setting up Sand Flat Tests

1. With temporary partitions, divide level surface of sand in flat (step B-5) into halves (for longleaf) or quarters (for other species).

2. Place counted subsamples of 100 seeds each on sand, at rate of 100 seeds per half flat for longleaf and 100 per quarter flat for other species; scatter seeds evenly to avoid contact between them.

3. Tamp longleaf, slash, or loblolly seeds gently to make sure each seed lies flat and none projects above top of flat. (Do not tamp shortleaf seeds; to do so may result in covering them too deeply.)

4. With partitions still in place, mark on the edges of flat, with crayon or soft pencil, the number and letter of each 100-seed subsample, and the ends of the strips occupied by the partitions.

5. Remove partitions.

6. Cover seeds with dry sand to slightly above edges of flat, being careful not to move seeds into contact one with another, or into or across space formerly covered by partitions.

7. Strike off excess dry sand level with edges of flat, by means of the straightedge.

8. Mark each 100-seed subsample with permanent cardboard or plastic label in pencil (ink will run), corresponding to temporary crayon label; mark boundaries between 100-seed subsamples with thumb tacks in edges of flats.

9. Water the dry sand until it appears about as moist as sand with which flat was originally filled. Recover carefully with sand any seeds exposed during watering.

10. Cover each flat with mouse-proof wire screen and place in germinating room to germinate, with thermometer in midst of flats.

D. Preparing Peat Mats

Mats sometimes mold if made too long before being used, but may safely be made any time within 5 days of setting up the tests.

1. Crumble some peat into tub; add water, mixing thoroughly, until all peat is moist and a little water can be squeezed from any handful picked up, but not until there is much free water in bottom of tub. Preferably, peat should stand at least an hour, but not over night, between wetting and use. The cooler the peat when molded into mats, the less will it stick to the mold.

2. Turn mold nail-side-up on table. From each end of a 36-by 3/4-inch strip of screen wire remove 3 cross-strands and bend the free ends of lengthwise wires at right angles to the strip. Stretch strip tightly around nails on mold, pinching corners square at nails; fasten shut by means of free ends of lengthwise wires to form a collar (fig. 54 A).

3. Fasten one lengthwise and one crosswise brace of fine copper wire across the collar, being careful not to pull ends or sides of collar inward (fig. 54 A).

4. Slip frame down over collar (fig. 54 B).

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Figure 54.--Construction and use of peat mat for germination test. A. Mold, with screen-wire collar and copper-wire crossbraces in place. B. Frame in place around collar; peat being compressed to 3/4-inch thickness. C. Mold removed from mat after inverting cover-glass, frame, and mold. D. Mat in place in dish; 200 longleaf seeds in place on mat.

5. Starting with the space under the intersection of the wire crossbraces, and going next to the sides and ends of the collar, fill the collar slightly more than level full of peat squeezed moderately free of excess water; be careful to get as little peat as possible between collar and frame. The exact level to fill to varies with texture and wetness of peat, and is determined by trial for each new batch.

6. With the hands, compress peat to a firm mat with a smooth surface level with the surface of the frame (fig. 54 B).

7. Lay a cover-glass over the exposed surface of the peat mat; holding glass, frame, and mold firmly together with both hands, invert them and lay them, glass-side-down, on the table.

8. The mold is now on top. Remove it gently, reaching in between mold and frame to remove collar from nails and work it down into frame again if collar catches on nails. Mat should present unbroken surface, as in fig. 54 C. If patches of peat remain sticking to mold, use colder water, squeeze peat drier, or rewax mold.

9. Lift frame from around collar, leaving finished peat mat on cover glass; be careful not to crack mat in process.

10. Hold cover-glass and mat over dish at slight slant. Hold finger of one hand against middle of long side of mat. With single quick, smooth movement of other hand, slide glass sidewise from under mat, allowing mat to drop unbroken into dish (fig. 54 D). Center the mat exactly in dish.

E. Setting up Peat Mat Tests

1. Thoroughly mix sample of seed and spread out on smooth surface, as cover-glass or sheet of letter paper.

2. Taking seeds at random in 2's and 3's, to a total of 25, push them from smooth surface onto $9\frac{1}{2}$- by 2-inch metal strip; push into approximately equal spacing along whole length of unbent edge of strip.

3. Holding strip by upturned edge, pour seed off unbent edge into first groove in surface of peat mat. Few of the seeds

should touch each other as they lie in the groove; if many touch, or any pile up, rearrange them with tweezers.

4. Repeat process with next 3 grooves, completing setting of 100-seed subsample.

5. Repeat on other half of mat (fig. 54 D), and on successive mats, till eight 100-seed subsamples have been set. (For assured accuracy, check count of 25 seeds in each groove.)

6. Label each 100-seed subsample with number and letter on bit of plastic tucked between peat and wire collar; be sure labels do not project above top of dish.

7. Pour water carefully between mat and side of dish until 1/8 to 1/4 inch deep; after some or all of it has soaked up, repeat, until 1/16 to 1/8 inch of free water remains in bottom of dish.

8. Place cover-glass over dish and place seeds to germinate. (Or place in refrigerator at 38° to 41° F. for pregermination treatment; 35° F. is too low for pregermination treatment of seeds on peat mats, as, even under cover-glasses, evaporation from the peat results in a temperature lower than that of the refrigerator.)

F. Care of Tests

1. Sand flats and peat mats should be inspected daily for moisture, progress of germination, and injuries.

2. Sand flats usually must be watered at least once a day--twice a day or more often if the humidity is low or there is much air movement. The sand in contact with the seed must be kept perceptibly moist at all times, but never so wet as to surround the seed with a film of water. After the first 2 or 3 days, peat mats seldom require watering more often than every fifth to tenth day.

3. Seed in sand flats must be kept covered 1/8 inch deep, measured to the center of the seed. Shallower covering may result in harmful drying and deeper covering may seriously reduce both rapidity and completeness of germination by cutting off light.

4. On peat mats some mold invariably develops. If it becomes very heavy, it may be broken up and removed with tweezers. In extreme cases, wash the seeds in tap water and transfer them to fresh mats.

5. Maggots are controlled by removing with tweezers.

G. Recording Germination

1. Record germination on suitable forms (A-5) every 5 or 7 days, whichever proves more convenient; if germination is so rapid as to confuse counts at these intervals, record it every 2 or 3 days.

2. Record germination both by calendar dates and by days since start of test. For example, if a test is set up January 24, record germination on February 8 as having been observed on the 15th day. To get the number of days, count all days, including the day of observation, after the day on which the flats or mats were first exposed to warmth and light. In the case of a sample first stratified and then tested in flats or on mats, this means only the days after it was transferred from the refrigerator to the germinating room, and does not include days in the refrigerator.

3. At each count, to simplify later interpretation of results, record separately, for each 100-seed subsample (A, B, ...H) the total normal germination percent to date. For each subsample, this is obtained by adding the percentage observed on the current day to the total percentage recorded at the last previous count.

4. In sand flat tests, count no seed as germinated until it has lifted its seed coat above the sand. If the sand tends to crust, the flat should be watered just before the count.

5. In peat mat tests, count no seed until the radicle (root) turns definitely downward.

6. Record the percentage of abnormally germinating seeds in each subsample by means of a dot-tally, without regard to date, in the space provided near the bottom of the form. If it is doubtful whether a seed is germinating normally, leave it until the next count to make sure. Common abnormalities are:
   (a) End-splitting, which includes conspicuous swelling, wide opening of the crack in the seed coat, and usually the protrusion of a small nipple, which, however, fails to elongate and turn downward.
   (b) Protrusion of a thickened, blunt, or sometimes conspicuously constricted horizontal radicle which, instead of turning downward, grows horizontally or even turns upward.
   (c) Similar horizontal elongation of the hypocotyl (seedling stem) practically without growth of the radicle.
   (d) Protrusion of the green cotyledons instead of the radicle. A gelatinous cap or coating on the protruding radicle is not of itself a sign of abnormality. Count a polyembrionic seed--one germinating with two or more radicles--as one normal seed unless germination is otherwise abnormal.

7. Pull and discard all normally and abnormally germinated seeds as counted, to simplify later counts and avoid counting any seed twice.

8. If the results of the test are to be used to determine sowing rate by the formula based on full seed only (p. 217), cut the seeds remaining ungerminated at the end of the test, and record for each subsample the percentages sound, spoiled, and empty. For each subsample, these percentages plus the total percentages of normal and abnormal germination at the end of the test should equal 100. Germination percent based on full seed only $= \frac{\text{(Total normal germination percent)}}{100 - \text{(Total percent empty)}} \times 100$, and is calculated from the average percentages for all subsamples.

ACIDIFICATION OF NURSERY SOIL TO CONTROL DAMPING-OFF

For acidifying soil to control damping-off, either sulfuric acid or aluminum sulfate may be used. Get the strongest commercial grade of concentrated acid (specific gravity at least 1.8), or the ordinary technical granular grade of aluminum sulfate—not "alum", which ordinarily means potassium aluminum sulfate.

Where rates of application have not been worked out and proved effective, apply either sulfuric acid or aluminum sulfate to small test plots at the rate most appropriate for the pH of the soil involved (table 31). A preliminary idea of effectiveness can be got from the pH concentration of the surface ½ inch on the treated plots, 3 days after treatment. If it has dropped below 4.0, the application has been too heavy; if it is still above 5.0, too light. If at all possible, a crop of seedlings should be grown on treated test plots before treating any large fraction of the nursery.

Aluminum sulfate may be applied dry, or dissolved in 1 to 2 pints of water per square foot (125 to 250 gallons per 1,000 square feet) of bed. Sulfuric acid is always applied in water solution. Wilde condemns strongly the usual recommendation of applying the acid in 1 or 2 pints of water per square foot of bed regardless of the amount of acid used, and emphasizes that, for effective control of damping-off without excessive injury to soil, the amount of water used must be such that the prescribed amount of acid per square foot is not more than 2.0 nor less than 1.5 percent, by volume, of the solution (Wilde, Acid, 1937)(___).

Table 31.--Quantities of sulfuric acid or of aluminum sulfate recommended for trial control of damping-off on various soils

Initial pH of soil	Sulfuric acid				Aluminum sulfate			
	Per square foot		Per 1,000 square feet		Per square foot		Per 1,000 square feet	
	Sandy soil	Heavy soil	Sandy soil	Heavy soil	Sandy soil	Heavy soil	Sandy soil	Heavy soil
	Fluid ounces		Gallons		Ounces		Pounds	
5.0	0	1/16	0.00	0.49	0	1/4	0.0	15.6
5.5	1/16	3/32	.49	.73	1/4	3/8	15.6	23.4
6.0	3/32	1/8	.73	.98	3/8	1/2	23.4	31.2
6.5	1/8	3/16	.98	1.47	1/2	3/4	31.2	46.9
7.0	3/16	1/4	1.47	1.95	3/4	1	46.9	62.5
7.5	1/4	5/16	1.95	2.44	1	1-1/4	62.5	78.1
8.0	5/16	3/8	2.44	2.93	1-1/4	1-1/2	78.1	93.7

The usual recommendation is to make the application immediately after sowing. This is feasible with southern pines only where a soil cover is used. With cloth or pine-straw bed-covers, treatment should precede sowing, and sowing should be done with the minimum possible freshening of the treated surface. Treated beds must be kept continuously moist until all seedlings have emerged, to prevent chemical injury to germinating seeds and small seedlings.

Sulfuric acid is corrosive to equipment, and usually requires lead-pipe sprinklers, paraffin-coated wooden vessels, and other special equipment for application. It is dangerous to handle. Workmen should wear felt or woolen hats, shirts, pants, and underclothes; face masks or goggles; rubber outer garments, especially boots, aprons, and gauntleted rubber gloves. Never open a sulfuric-acid container with the face over the opening or with the opening toward another person. Never empty it by any pressure method; pour or siphon out the acid. Never pour water into sulfuric acid; always pour the acid into the water, slowly. Do not use sulfuric acid without carefully instructing crew in safe handling, and in first-aid measures for acid burns. The Interstate Commerce Commission has strict rules concerning the labelling and shipment of sulfuric acid, and return of containers. For further details, see latest Department of Labor safety rules for use of sulfuric acid (obtainable from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.) and the Red Cross first-aid textbook. (American Red Cross, 1945; Baxter, 1943; Boyce, 1948; Davis, Wright, and Hartley, 1942; Hartley 1935; Wilde, Acid, 1937)(___, ___, ___, ___, ___, ___)

DIRECTIONS FOR SEEDLING INVENTORIES

A. Equipment and Materials

1. One or more sampling frames, light, but rigid enough to prevent distortion in handling; each exactly 1 foot wide (inside measurement), and long enough (usually 4 feet) to cover the width of the bed occupied by seedlings. Steel welding rods, or flat steel strips reinforced with 1 or more cross bars, make a satisfactory frame.

2. Published set of random numbers (Munns, Hoerner, and Clements, 1947; Snedecor, 1946)(___, ___), or 2 sets of lotto or bingo numbers running from 0 to 40 (for 400-foot beds; from 0 to 50 or 100 for beds 500 to 1,000 feet long) and 0 to 9, respectively.

3. Steel tape 50 or 100 feet long.

4. Detailed map of nursery showing species, seed sources, dates of sowing, and variations in cultural treatment for crop of seedlings to be inventoried, together with location of sprinkler lines and individual beds.

5. A supply of record forms, headed as follows, with 20 or 25 lines per sheet:

_______________ Nursery Inventory
(Name)

Compartment number_______________ Species_______________

Date of inventory_______________ Seed source_______________

Recorder_______________ Date sown_______________

Measurement started N E S W end of bed (circle one). Cultural treatment_______________

Uniformity of stocking_______________

Bed number	Distance along bed	Living seedlings	Plantable seedlings	Bed number	Distance along bed	Living seedlings	Plantable seedlings
	Feet	- - Number	- -		Feet	- - Number	- -

6. If the percentages of living seedlings which are plantable are to be determined by examining roots as well as tops, an ample supply of tall, stiff wire pins, looped at the top and flagged with bright cloth.

B. Preparation for Sampling

1. Determine the units (p. 262 and table 19) into which the nursery must be divided for inventory. Mark these units plainly on the nursery map and label each in terms of species, seed-source, period of sowing, distinctive cultural treatment, damage, and uniformity of stocking.

2. Choose a suitable intensity of sampling for each unit and determine the number of samples to be counted by using as guides table 19, its footnote 1, and the uniformity of the stands. As an example, assume an October inventory of a nursery unit of twenty 400-foot beds which inspection and ocular estimate or a few preliminary counts show to be fairly uniformly stocked at a rate of about 30 seedlings per square foot. Such a unit, which should contain almost 1,000,000 seedlings, might best be inventoried by means of a 2-percent estimate. This would require counting 160 samples, 8 samples per bed. For units containing different numbers of beds, see table 19; for beds of unequal sizes, see p. 262.

3. Fill out the headings at the top of enough forms to hold the counts of seedlings in the samples for each nursery unit. Entries at the tops of the forms will correspond essentially to unit labels on the nursery map.

4. Select, by means of the table of random numbers (or lotto numbers), the points at which the beds within the unit are to be sampled and enter their positions on the forms in numerical order from the north end (to choose a specific illustration) of the lowest-numbered bed in the unit to the south end of the highest-numbered bed. (In the present example, with 8 samples to be taken in each 400-foot bed, locate the sampling points for each bed in turn by drawing, at random, 8 different numbers within the range, 1 to 400, inclusive.) Arrangement in numerical order on the form is essential to prevent confusion and back-tracking while counting samples in the nursery.

5. If the plantable seedlings in the unit are to be estimated by digging part of the samples, choose 20 sampling positions (or up to 40 if seedling development is very irregular), by means of the table of random numbers, from the entire series of sampling positions listed on the forms. Circle the chosen positions in red on the forms so that the corresponding samples can be marked with wire pins when counted.

C. Making Sample Counts

1. In the nursery, pace down the first bed of the unit to the point where, as indicated on the prepared form, the first sample is to be taken. (If blank spaces occur in the bed, do not count the steps required to pass them.) Mark the distance paced in the nursery path, without examining the bed.

2. Turn to the bed and ease the sampling frame down among the seedlings, at right angles to the length of the bed, and exactly opposite the distance mark in the path. Do not move the frame to either side to include or exclude better or poorer looking portions of the seedling stand; doing so almost invariably reduces the accuracy of the inventory.

3. Count the living seedlings within the frame, and record the number on the form in the column headed "Number of living seedlings," opposite the distance designating the position of the sample. Except with longleaf, count only those seedlings whose root collars lie wholly inside the frame; with longleaf, count any seedling having half or more of its root diameter inside the frame.

4. If the number of plantable seedlings is to be estimated on the basis of top development, count also, in each sample, the seedlings whose tops indicate they will be plantable at lifting time. Record the number of plantable seedlings to the right of the number of living seedlings.

5. If the number of plantable seedlings is to be estimated on the basis of both root and top development, mark the red-circled samples (B-5) with a stiff wire pin at each corner, before removing the frame. After the living trees in all samples have been counted (C-3), go back and dig up each pinned sample, being careful to take only the seedlings originally within the frame. Grade the seedlings and, in the appropriate column, record the number plantable.

6. When all samples have been counted, tape and record, for the nursery unit as a whole, the total net length of seedbed actually occupied by seedlings (p. 264). In the present example, assume that the total net length of the 20 beds is 7,880 feet.

D. Calculating the Number of Living Seedlings

1. Add the numbers of living seedlings (C-3) in all samples. In the present example, assume that the total for the 160 samples is 17,536 live seedlings.

2. Compute the estimated total number of living seedlings in the unit by the formula:

$$\frac{\text{Estimated total number}}{\text{Total length of bed occupied (feet)}} = \frac{\text{Total living seedlings in samples}}{\text{Number of 1-foot-wide samples}}$$

Using the values assumed in the present example,

$$\frac{\text{Estimated total number}}{7{,}880} = \frac{17{,}536}{160}$$

$$\text{Estimated total number} = \frac{(17,536)(7,880)}{160}$$

Estimated total number = 863,648 living trees.

E. Calculating the Number of Plantable Seedlings

1. If the total percentage of seedlings lost each year through fall mortality and through lifting and culling is fairly constant and is known, this figure may be subtracted from 100 and the estimated total number of living seedlings may be multiplied by the difference, with two decimal places pointed off, to get the total number of plantable seedlings.

2. If counts were made of plantable seedlings in all samples on the basis of top development alone (C-4), the estimated total number of plantable seedlings may be calculated by the formula in D-2 by substituting the plantable count for the living tree count. It may be corrected as in E-1 to allow for losses during lifting and for trees with acceptable tops but inadequate roots.

3. If the seedlings in 20 or more of the samples have been dug up and graded (C-5), multiply by 100 the number plantable in each sample, and divide the product by the total number of living seedlings (C-3) in the same sample. Next, on a sheet of cross-section paper, plot the 20 plantable percents so computed, each over its corresponding total number of live seedlings, and fit a straight line curve to the resulting points. Third, compute for the total of all the samples counted the average number of living seedlings per frame. (In the present example: $\frac{17,536}{160} = 109.6$). Fourth, from the straight line curve, read the plantable percent corresponding to the average number of living trees per frame for all samples. Fifth, multiply the estimated total number of living seedlings (D-2) by the percentage read from the curve to get the estimated total number plantable. Sixth, correct the estimated total number plantable as in E-1, to allow for losses during lifting.

DIRECTIONS FOR PREPARING COMPOST FROM RICE OR OTHER STRAW 54/

54/ Except as specifically noted, taken from (Cossitt, 1938) (___) and unpublished data, U. S. Forest Service.

Compost baled rice straw in a nearly square pile of convenient length and width--the larger the better--and 6 to 10 feet high; settling during composting will considerably reduce the original height. Build the pile on level, heavy clay soil, with an open drainage ditch under the pile leading to an outside sump, from which liquid percolating through the pile can be dipped or pumped back onto the compost.

Make the outside walls of the pile of intact bales, to prevent caving, and the interior of loose straw, enriched with the following "reagent" adapted from (Smith, Stevenson, and Brown, 1930)(___) at the rate of 150 pounds per ton of air-dry organic matter, side walls included:

	Percent	Pounds per ton of air-dry raw material
Ammonium sulfate	45	67.5
Rock phosphate, ground to pass 200-mesh sieve	23	34.5
Finely ground limestone	32	48.0
Total	100	150.0

Spread the straw in the interior of the pile in layers, each only a few inches deep and each covered with a proportionate amount of the reagent. The more uniformly the straw and reagent are mixed, the more rapid and complete the decomposition of the straw and the more uniform the resulting compost.

Add water during and immediately after piling, to a total of about 500 gallons per ton of air-dry material. Thereafter, water artificially from the sump or other sources as needed to keep the pile thoroughly and continually moist until decomposition of the straw in the interior is complete. Decomposition usually requires at least 8 to 10 months, after which the compost may be used immediately or stored in the pile 2 to 8 months longer, as best fits the nursery schedule.

Well decomposed compost from the inside of the pile should be free from large lumps of undecomposed straw, and have the consistency and odor of well rotted horse manure. The top and sides of the pile

will dry out too much to decompose well, but the sides presumably will absorb a good deal of the reagent. Undecomposed top and side material from an old pile should be mixed uniformly with fresh straw in the inside of a new pile the following year.

Rice straw may be replaced with other grain straw. Any straw may be supplemented with legume hay, grass clippings, forest litter, leaves, or other available organic materials except cone scales and seed wings--even with weeds if they have been pulled before going to seed. When wet or green material is used, its dry weight should be estimated from special records or tests, and the reagent added in the same proportion as for dry rice straw.

A 3-year average total prewar cost for such compost at one U. S. Forest Service nursery was \$3.03 per ton, wet weight, or \$9.94 per ton, oven-dry weight. Applications have usually been from 1/8 to $\frac{1}{4}$ inch deep, broadcast, or $\frac{1}{4}$ to $\frac{1}{2}$ inch deep, on "sore spots" such as sheet-eroded areas. Based on these prices and on conversion figures from (Muntz, 1944)(___), 1/8-, 1/4-, 1/2-, and 1-inch applications would cost \$28.60, \$57.20, \$114.40, and \$228.80 per acre, respectively, exclusive of spreading.

There is some question about the amount of lime to include in the reagent. Presumably it improves decomposition of the straw, but on some soils $\frac{1}{2}$- to 1-inch applications of compost containing 48 pounds of lime per ton of air-dry straw might increase the calcium content or reduce acidity undesirably. This should be investigated currently by pH determinations of the compost and of compost-treated and untreated soils, and by close watch of seedlings for early mortality or damping-off and for later chlorosis and other signs of nutritional maladjustment. The composting processes recommended in (Wilde, 1946)(___) omit the use of lime.

DIRECTIONS FOR HEELING-IN SEEDLINGS

1. Select a suitable place, free from stones, gravel, and tree roots. A level or slightly sloping, well drained area is preferable to one poorly drained or very steep. Sandy or loamy soil is desirable because it makes digging, correct covering, and watering easier, but is not essential. Natural or artificial shelter from wind and sun is desirable, but not essential for storage up to 3 or 4 weeks. The area selected should be accessible to transportation, water, and the work. The space required varies, depending upon the size of the stock, but plenty should be allowed.

2. Clear any grass from the heel-in bed; extra clearing may be desirable for fire protection.

3. Dig a trench 2 to 4 inches deeper than the seedling roots are long, and with one side smooth and slightly sloping. For southern pine seedlings root-pruned to 8 inches, make the trench 10 to 12 inches deep. The smooth side should slope just enough so that either loose or bundled seedlings laid against it, with their roots in contact with the smooth earth all the way down, will not topple. If the ground is not level, dig the trench on the contour. An ordinary long-handled, round-pointed shovel is the best hand tool for digging the trench; the standard planting bar is inefficient. For heeling-in large quantities of stock, a plow may be adapted to make suitable trenches.

4. Stand the seedlings in a shallow layer against the sloping side of the trench, with their root collars 1 to 2 inches below the surface of the undisturbed soil, and their roots unbent and in contact with the side of the trench throughout their length. If the seedlings are loose, they should form a layer preferably only 2 or 3 inches, and never more than 4 inches, thick. If they have been tied in bundles of 50 or 100, the bundles need not be cut open and spread out, but should be packed closely together, in a layer only one bundle thick, along the side of the trench.

5. Depending on the quantity of stock to be heeled-in, either (a) fill the trench carefully to a level 1 to 2 inches above the root collars of the seedlings, packing the earth against the roots at intervals during filling; or (b) carefully pack a 4-to 6-inch layer of earth against the roots, leaving the packed surface at the same slight slope as the original sloping wall of the trench. Step b is used when one or more additional layers of seedlings are to be heeled-in; in such cases repeat steps 4 and 5b as many times as needed, standing seedlings against successive 4- to 6-inch layers of packed earth, and widening the original trench as required. In any case, be careful not to bend the roots excessively, to leave roots uncovered, or to force the root collars more than 1 or 2 inches below the soil surface.

6. Thoroughly water the soil on both sides of all rows of seedlings, washing off in the process any loose earth on the tops.

7. Inspect each row thoroughly to make sure all filled-in soil is firmly packed, all root collars are at least 1 inch below the level of the soil, and no tops are covered above the bottom one-fifth of their length. Correct any mistakes found. Pay special attention to the ends of the rows, where seedlings are most likely to be insufficiently covered.

8. Mark the ends of the row, or of the first and last rows, **with stakes plainly labeled to show** (a) the stock lot and (b) the date of heeling-in. Without such labels the identity of the stock may be permanently lost, and the stock itself may die from overlong storage.

9. Water the stock in the heel-in bed often enough to keep the soil continually moist.

DIRECTIONS FOR BALING SEEDLINGS

A. Equipment

1. Tank or trough for soaking sphagnum moss.

2. Fork for handling wet moss.

3. Wooden or reinforced hardware-cloth screen for draining excess water from moss. (A clothes-wringer may be used instead.)

4. For each baler, a table at least 4 feet long by $2\frac{1}{2}$ feet wide, of convenient height, with 10- or 12-inch side supports (fig. 26, p. 271).

5. For each baler, a Signode strapping machine (Signode Strapping Machine Company, New Orleans, Louisiana; Chicago, Illinois), or equivalent, for tightening and fastening metal strap 3/8 inch wide. Despite the cost, it is cheaper to have one or two extra machines on hand than to incur a break-down in packing through the failure of one.

B. Material per Bale

1. Two wooden slats 1 by 2 by 24 inches. (For very tall seedlings, 36-inch slats.)

2. One waterproof wrapper 6 by 2 feet (for very tall seedlings, 6 by 3 feet), of 7-ounce burlap backed with asphalt and kraft paper, or of heavy water-proof crepe paper reinforced with sisal fibers. The essentials are: (a) sufficient toughness to stand packing and shipping; and (b) resistance to water sufficient to keep bale from drying out and, if bales are shipped by express, to meet common-carrier's requirements about avoiding injury to other merchandise. For latest specifications, sources, and prices, write Regional Forester, U. S. Forest Service, Atlanta, Georgia.

3. Supply of sphagnum moss. (Left-over moss may be stored dry in the bales in which purchased, or, after drying in shallow layers, in indoor bins or piles, until the following year.)

4. Two 3/8- inch by approximately 5-foot metal straps, to fit make of strapping machine used.

5. Two fastening seals.

C. Baling

1. Lay two straps across the table, about 18 inches apart. (The distance apart depends on the size of the seedlings and the way they go together in the bale, as explained in <u>5</u> and <u>10</u>, following.)

2. Lay one slat at right angles across the straps.

3. Lay a wrapper, with its long dimension across the table (fig. 26 A), on top of the straps and slat.

4. Across almost the full width of the wrapper spread a layer of drained or wrung-out sphagnum moss 18 to 24 inches wide from front to back, and thick enough ($2\frac{1}{2}$ to 3 inches) to protect the seedlings.

5. On the layer of moss place loose or bundled seedlings with the sparser lower parts of their root systems overlapping over the center-line of the wrapper and their root collars well inside the edges of the wrapper, but at least the tips of their needles projecting well beyond the wrapper (fig. 26 B). The seedling tops, however, should not project so far beyond the wrapper as to flop loose or to be injured in handling the bale. The layer of seedlings should not be more than 3 to 4 inches thick. The exact position of the seedlings depends mainly on their size. On each side of the layer the root collars should be about equally distant from the edge of the wrapper.

6. Spread 2 to 3 inches of moss over the roots and far enough up the stems to cover the root collars and to maintain the thickness of the bale to a point slightly outside the strap on either side. The moss must extend beyond the seedlings, both front and back, to meet the first layer of moss.

7. Repeat steps 5 and 6 until the bale is the desired size, ending with a top layer of moss $2\frac{1}{2}$ to 3 inches thick (fig. 26 A). (Numerous thin layers of seedlings and moss require little more labor than fewer, thicker layers, and make a better bale, especially for long shipment or several days' storage.) The U. S. Forest Service generally makes up bales to weigh about 60 pounds apiece, before supplementary watering, letting the number of seedlings per bale vary according to the size of the stock. With a little practice, checked by weighing of bales, most bales can be made remarkably uniform.

8. Making sure that there is everywhere at least a $2\frac{1}{2}$-to 3-inch layer of moss between the wrapper and the nearest seedling roots, bring the two ends of the wrapper neatly together in a double layer above the top of the bale.

9. Take the second slat and roll both ends of the wrapper jointly around it until the wrapper has pulled the bale together as tightly as can be managed conveniently by hand (fig. 26 B).

10. Bring the straps around the bale; tighten each firmly but not crushingly with the strapping machine (fig. 26 B); seal and cut off. The straps must go around the bale fairly near the edges of the

wrapper and somewhat above the root collars of the seedlings (less far, but still definitely above, in the case of longleaf pine) in such a way that rough handling cannot cause the seedlings or straps to loosen or shift, or seedlings or moss to fall out.

11. The finished bales are kept on their sides but may be stood on end, temporarily, for watering and draining before or during shipment or storage.

DIRECTIONS FOR CORRECT PLANTING WITH HAND TOOLS

Although breaking them down into numbered steps makes the following directions lengthy, it permits teaching planters to perform each step correctly, with minimum expenditure of time and energy, <u>and to save waste motions.</u> For example, the 14 steps in the first method described, once mastered, flow smoothly into each other and are performed in from 20 to as few as 10 seconds.

At the completion of planting by any of the methods, the root collar of the seedling should be at the surface of the soil unless for special reasons it has been ordered set slightly below. A change from greenish to yellowish bark marks the root collar of most seedlings.

The directions are for right-handed planters. For left-handed planters, right and left should be reversed.

<u>Bar Planting with Standard Bar and Ehrhart Tray, Each Man Carrying and Setting his Own Trees</u>

1. Hold tray in left hand (sloping end, with seedling tops, to rear) and bar in right hand (with step turned to right); select planting spot.

2. Set tray down to left of and slightly beyond planting spot, out of way but within easy reach (fig. 34 <u>B</u>, p. 347).

3. With one or two strokes of right heel or of bar blade, clear 4-by 6-inch strip of all grass and trash. (Heel preferred if planter's shoes are good. Bar must be used if shoes are poor; it takes about 10 percent longer. Not more than a couple of seconds should be spent clearing the spot.)

4. Using both hands, and with bar inclined slightly toward body so that far side of <u>blade</u> is <u>vertical,</u> sink blade full length into soil to make planting slit at least 4 inches beyond the near end of cleared strip (fig. 55, <u>A</u>). Use right foot on step if hardness of ground requires it.

Figure 55.--Bar planting, with each man carrying and setting his own trees. <u>A</u>. Starting the planting slit; face is vertical. <u>B</u>. Enlarging the planting slit and loosening bar. <u>C</u>. Inserting seedling in slit till root collar is below surface of soil. <u>D</u>. Raising root collar to soil surface. <u>E</u>. Closing top of planting slit to hold seedling temporarily in place. <u>F</u>. Making closing slit and packing soil firmly against roots, without disturbing face.

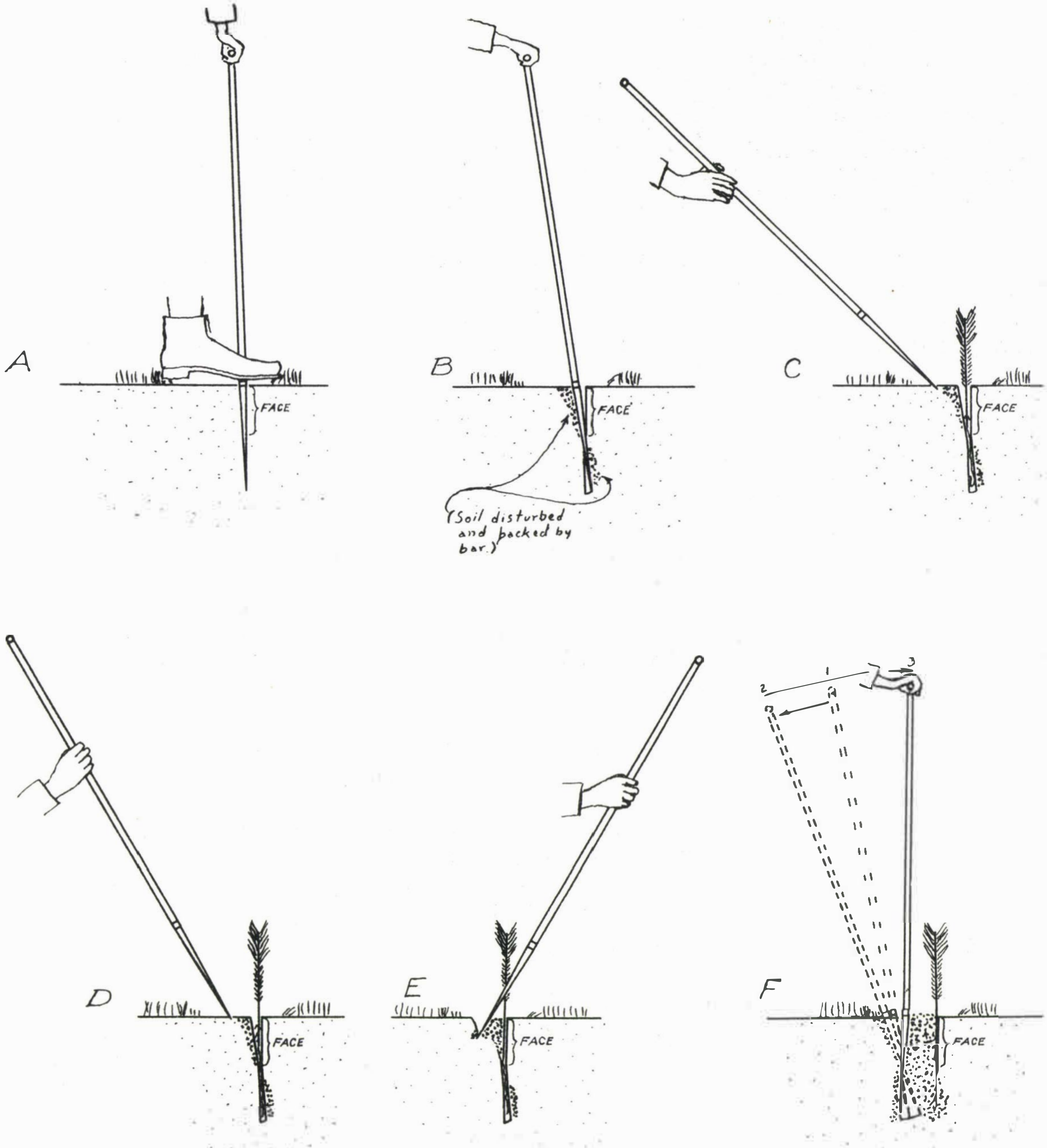

Figure 55.--Bar planting, with each man carrying and setting his own trees. A. Starting the planting slit; face is vertical. B. Enlarging the planting slit and loosening bar. C. Inserting seedling in slit till root collar is below surface of soil. D. Raising root collar to soil surface. E. Closing top of planting slit to hold seedling temporarily in place. F. Making closing slit and packing soil firmly against roots, without disturbing face.

5. Pull handle of bar about 4 inches toward body to open top of planting slit a maximum of about $1\frac{1}{2}$ inches and to loosen blade in soil (fig. 55, B). Do not push bar from body; to do so will disturb face of planting slit (fig. 55, A and F), which should remain vertical and intact to keep seedling upright and (theoretically at least) to insure maximum movement of water through soil to roots.

6. Withdraw bar from slit.

7. Set edge of blade 2 inches behind rear edge of planting slit (fig. 55, C), supporting bar by shaft with right hand.

8. Drop to right knee (or bend over or squat); with left hand take one seedling from tray and insert roots in planting slit so that they are not doubled up and so that root collar is 1 to $1\frac{1}{2}$ inches below surface of soil (fig. 55, C).

9. Shake seedling and raise root collar to soil surface to insure straightness of all roots (fig. 55, D).

10. Holding seedling upright and at correct depth with left hand, thrust bar blade about 2 inches into soil with right hand and swing handle forward as in figure 55 E so that earth forced into top of planting slit holds seedling in position.

11. Release seedling from left hand; rise to feet, set bar $3\frac{1}{2}$ to 4 inches back of seedling stem, and drive blade full length into soil to make closing slit. Bar should be at angle indicated in position 1 in figure 55 F so that cutting edge will miss roots at bottom of planting slit by about $2\frac{1}{2}$ inches.

12. Pull bar handle about 6 inches toward body, to position 2 of figure 55 F, to close bottom of planting slit; then thrust it forward 12 or 14 inches to position 3 to close top of slit, but not far enough to hump up earth excessively or to move seedling from vertical.

13. Withdraw bar from closing slit, take in right hand, pick up tray with left hand, set right heel across closing slit, and in stepping forward mash earth into closing slit and firm it against seedling on same level as surrounding ground.

14. Pace distance to next planting spot.

Bar Planting with Standard Bar, Men Working in Pairs

Exactly as in preceding, except that steps 7 and 10 are omitted, and second man handles tray or other container in steps 1, 13, and 14 and performs steps 8 and 9, holding seedling in place till the barman has completed step 12. A right-handed tray man usually works on the barman's right, a left-handed tray man on his left.

Mattock (Grub Hoe) Center-hole Planting

1. Approach planting spot with tray in left hand, grub hoe in right.

2. Set tray down to left of and slightly beyond spot.

3. With grub-hoe blade, clear all grass and trash from 12- by 12-inch square.

4. With fewest possible strokes, dig hole slightly wider and deeper than root system; pile earth from hole compactly to right of hole and break up any large, hard lumps with blade.

5. Lay grub hoe down to right of pile.

6. Drop to right knee (or bend over or squat), and with left hand take one seedling from tray.

7. Gaging depth by eye, and using right hand, fill bottom of hole with loose earth to point slightly above maximum depth of root system.

8. With seedling in left hand, spread lowest root tips out on loose earth in hole.

9. Fill hole half full of loose earth with right hand, spreading and sifting earth under and among lower roots and firming it with right fist.

10. Holding seedling vertical with left hand, similarly fill rest of hole to slightly above surrounding ground level; this should bring loose earth just above root collar of seedling.

11. Pick up tray in left hand and grub hoe in right, rise to feet, place balls of feet on loose earth on either side of seedling, and jounce once to pack earth level with root collar.

12. Pace distance to next spot.

In center-hole planting the roots are spread fairly naturally in all directions and are surrounded entirely by loosened soil (fig. 56). The method is especially applicable on stony sites, hard soils, and with large-rooted planting stock, but is slow.

Mattock (Grub Hoe) Side-hole Planting

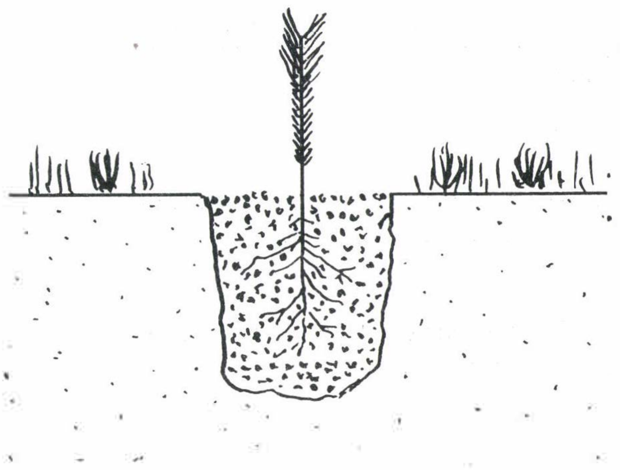

Figure 56.--Center-hole planting with mattock or grub hoe. The roots are well spread, and surrounded by loosened and repacked soil.

1, 2, and 3. As in center-hole planting.

4. Sink grub-hoe blade vertically into soil, full length, beyond middle of cleared square, and drag toward body and upward to make hole with smooth, vertical face (fig. 57) on far side. (In hard soil two or more strokes will be needed.) Pile earth compactly to right of hole, crumbling with blade if in hard lumps.

5. Lay grub hoe down to right of pile.

6. Drop to right knee; with left hand take one seedling from tray and place its roots against vertical far wall of hole, with root collar exactly at surface of ground.

7. Holding seedling upright in position with left hand, fill hole half full of loose earth with right hand, working earth among roots toward center of hole, and packing with right fist.

8. Still holding seedling upright with left hand, fill rest of hole with right hand, to slightly above level of root collar and surrounding ground.

9. Pick up tray with left hand and grub hoe with right. Rise to feet, and step on loose earth with ball of right foot to pack it level with surrounding surface.

10. Pace distance to next spot.

The side-hole method is somewhat quicker than the center-hole, and has the added possible

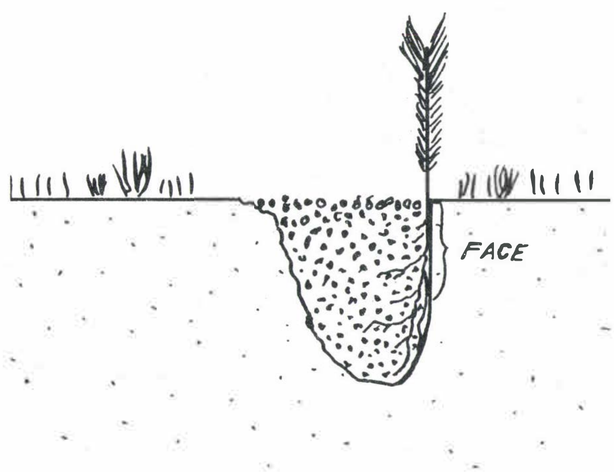

Figure 57.--Side-hole planting with mattock or grub hoe. The roots are partly spread out in loosened and repacked soil, partly in contact with vertical face of undisturbed soil.

advantage that part of the roots are in contact with soil of undisturbed structure.

Mattock (Grub Hoe) Slit Planting with Narrow-Bladed Tool in Light Soil

1, 2, and 3. As in center-hole planting.

4. Sink blade full length into soil near center of cleared square, as nearly vertically as possible (position 1, fig. 58, A).

Figure 58.--Slit planting with narrow-bladed mattock or grub hoe in light soil. A. Opening the slit. B. Seedling in final position before blade is withdrawn.

5. Raise handle slightly to position 2 of same figure, then drag strongly backward and downward to position 3, leaving about 1 inch between far side of blade and far side of slit.

6. With right hand still pulling strongly on handle, near blade, drop to right knee.

7. With left hand take one seedling from tray; insert roots, without doubling them up, between blade and far side of slit, till root collar is 1 to $1\frac{1}{2}$ inches below soil surface.

8. With left hand shake seedling to straighten root tips, and raise root collar to soil surface (fig. 58, B).

9. Holding seedling vertical and at correct depth with left hand, withdraw grub hoe from slit with right hand, and by a poke with the blade close the top of the slit enough to hold the seedling temporarily in correct position.

10. Keep grub hoe in right hand, pick up tray in left hand, rise to feet, and close slit completely and level with surrounding surface with one or two downward and forward thrusts of right heel.

11. Pace distance to next spot.

Mattock (Grub Hoe) Slit Planting with Broad-bladed Tool or in Heavy Soil

1, 2, and 3. As in center-hole planting.

4. Drive blade full length into soil at far side of spot, at angle which will bring cutting edge 8 inches below surface (position 1, fig. 59, A).

Figure 59.--Slit-planting with mattock or grub hoe in heavier soil. A. Opening slit. B. Seedling in final position before closing slit.

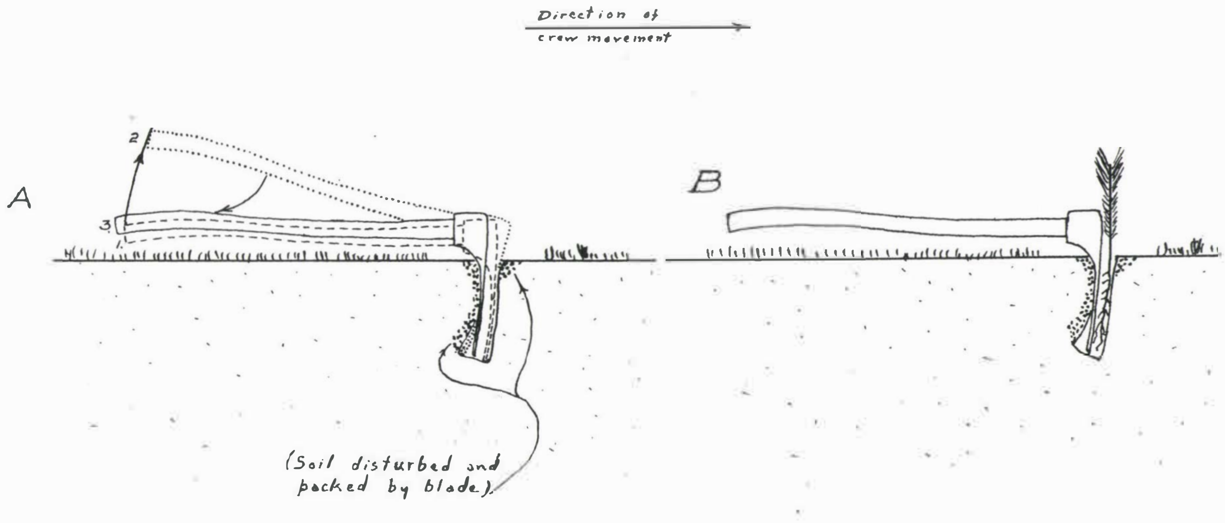

Figure 58.--Slit planting with narrow-bladed mattock or grub hoe in light soil. A. Opening the slit. B. Seedling in final position before blade is withdrawn.

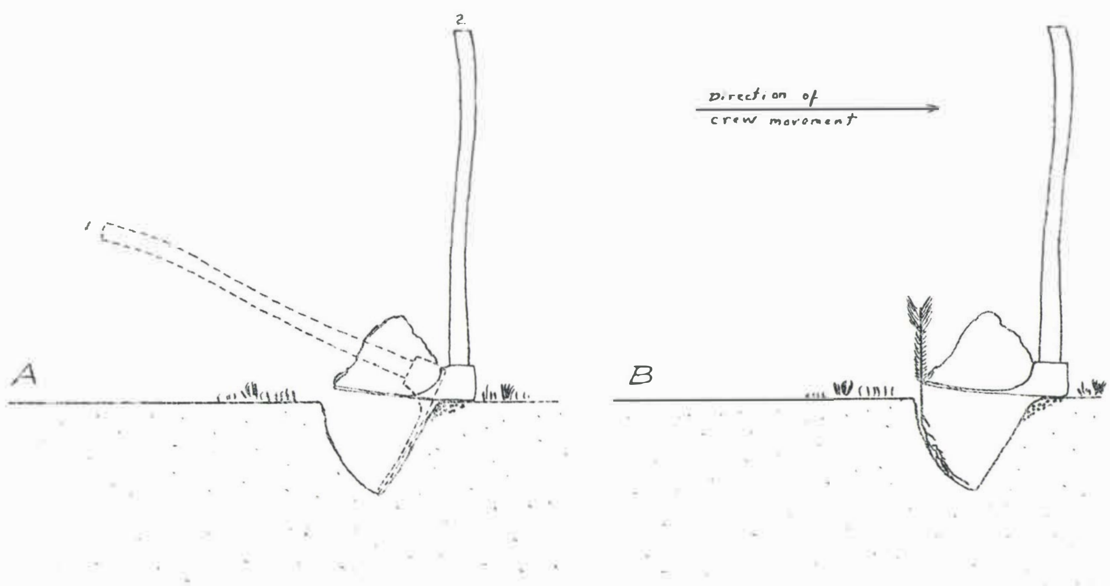

Figure 59.--Slit-planting with mattock or grub hoe in heavier soil. A. Opening slit. B. Seedling in final position before closing slit.

5. Turn handle of grub hoe upright to position 2 of same figure, until 1-inch-wide gap appears between edge of hole in ground and edge of blade with its clod of earth. (In some soils the blade does not have to be turned entirely out of ground to open wide enough gap.)

6. Holding handle in position 2 with right hand, drop to right knee, take one seedling from tray with left hand, and insert in gap, with roots as straight as possible and root collar 1 to 1½ inches below soil surface.

7. Shake seedling with left hand and raise root collar to soil surface (fig. 59, B).

8. Holding seedling upright and at correct depth with left hand, rock grub hoe back with right hand to position 1 of fig. 59, A, replacing clod of earth in hole to cover roots.

9. Release seedling with left hand, withdraw grub hoe from soil with right hand, pick up container with left hand, rise to feet, and set right heel firmly on loosened clod of earth to pack and level it.

10. Pace distance to next spot.

DIRECTIONS FOR CONTROL OF POCKET GOPHERS 55/

55/ Based on (Ceremello, "Gophers," 1938; Crouch, 1933; McPherson, "Gophers," 1940)(___, ___, ___) and unpublished data, U. S. Forest Service.

Initial control of pocket gophers (pp. 382 to 383) by either traps or poison may be before, during, or even considerably after planting, depending upon when burrowing or injury first becomes noticeable. Retreatment at one- or two-year intervals frequently is necessary.

Effective, economical control depends upon: (1) general preliminary information concerning the location, extent, and seriousness of gopher infestations; (2) thorough coverage, by the control crew, of each area treated; and, (3) intimate knowledge, on the part of each member of the control crew, of the burrowing habits of the gophers. In any one locality, gopher burrows usually follow a distinct pattern. Learning this pattern, by a little systematic digging, probing, and observation, greatly reduces the time required to place either traps or baits effectively.

The U. S. Forest Service has obtained good coverage of treated areas by two methods. One is to have a special crew gridiron the area at 10- to 25-foot intervals, either before or after planting, and treat all active gopher colonies found. The other is to have in each planting crew a few men trained and equipped for gopher control, and to have them treat all colonies discovered during planting.

Scouting for and treatment of pocket gophers, and checking on the success of treatments, must be done mostly during the season of active burrowing, usually from November to the middle of May.

Trapping

Satisfactory traps, which require no bait, are advertised in nursery journals and agricultural supply catalogues. Current recommendations may be obtained from the Fish and Wildlife Service, U. S. Department of Interior, Washington, D. C.

To set traps, locate a lateral or main burrow 12 to 18 inches from an obviously fresh mound, by probing with a $\frac{1}{2}$-inch iron rod, and cut into it with a shovel. Clear the loosened earth from the burrow with a spoon, disturbing the burrow walls as little as possible. Set two traps as far within the burrow as convenient, one on each side

of the hole to insure the gopher's running into a trap either way he comes. Set the treadles lightly and fasten each trap, by a soft, flexible wire, to a stake at one side. Fill the hole, but not quite completely; leakage of a little light seems to tempt the gopher to repairs. Revisit the traps as frequently as conditions warrant, emptying them and resetting them near the freshest neighboring mounds. If many gophers are present traps will usually be sprung within 24 hours; in active, previously untrapped colonies they may be sprung within 20 minutes.

Poisoning

Poisons may be applied in any one of several baits (p. 534). If fresh mounds in the treated area a few days after baiting show that one bait has failed, try another.

Go back and forth over the infested area at 10- to 25-foot intervals, probing for burrows. Wooden, iron, or iron-shod probes about the diameter of a broom-handle, sometimes equipped with foot-rests, are used. Burrows will be found mostly near or between fresh mounds. Probing is easiest when the soil is moderately moist.

Wherever the probe enters a burrow, drop in one or two pieces of poisoned carrot or sweet potato, or 1 tablespoonful of poisoned wheat, rolled oats, or milo maize. Be careful to thrust the probe only <u>into</u> the burrow, not through into its bottom, lest the bait go too deep and be overlooked. The probe hole need not be closed.

Evidence of successful poisoning is lack of fresh mounds on the area a few days or weeks after treatment. This lack is most easily checked after a hard rain.

DIRECTIONS FOR CONTROL OF TEXAS LEAF-CUTTING ANTS 56/

56/ Based on (Johnston, 1944; Nicholas, 1940)(___, ___), unpublished reports by Peter J. Ceremello, formerly of the Kisatchie National Forest, and unpublished data.

On sizeable areas in Louisiana and Texas, the U. S. Forest Service has controlled Texas leaf-cutting ants effectively with methyl bromide (p. 517) by combining methods developed for this chemical by the U. S. Bureau of Entomology and Plant Quarantine with techniques previously developed by the Forest Service for applying carbon disulfide (p. 515). Costs, before World War II, averaged about $3.00 per acre of colony treated, and about $.02 per acre of plantation protected.

The success attained has depended on: (1) utilizing all the evidence described on pp. 384 to 385 to find and identify any colonies; (2) confining treatment to the period between the first hard frosts and some time in March; (3) treating (with carbon disulfide especially) only when the temperature was above freezing but still low enough that the ants remained in the nest; (4) treating in advance of planting; (5) treating immediately, regardless of weather, when active colonies were discovered on areas being planted; and (6) retreating during the same or following seasons whenever earlier treatment failed to eradicate the colony. No chemical tested has been appreciably successful in hot weather. Methyl bromide or carbon disulfide is largely wasted if applied late in the morning or during the afternoon of warm, bright days in winter, when most of the ants are out of the nest. Planting within foraging distance of a nest should be stopped until treatment has been applied. Unless these precautions are taken, ants may attack and defoliate seedlings within ten minutes of planting.

Treatment with Methyl Bromide

Methyl bromide has many advantages over carbon disulfide in killing town ants (Johnston, 1941)(___). It is non-inflammable and non-explosive. It requires no special containers, as it can be bought in 1-pound sealed cans for which band applicators are obtainable. The rubber tubes required for use can be attached directly to these applicators. Only 1 pound of chemical is needed for colonies under an acre in size, and 1 pound per acre for larger colonies. Methyl bromide is applied only to the central parts of small colonies, and only in about 4 holes per acre in large ones. Neither treated nor untreated holes need be closed. Because of these advantages, 1-man crews can, if desired, treat all colonies of ordinary size.

Methyl bromide, despite its non-inflammability, must be handled with caution. Sealed in 1-pound containers it is largely liquid, but develops high pressures; extreme care must therefore be used in opening the can with the band applicator, lest the chemical be sprayed on the body. At ordinary pressures and temperatures, it is a gas. Excessive inhaling of the gas results in dizziness, vomiting, and double vision. In extreme cases it may be fatal. Continued exposure to the liquid or gas may result in burning. Oil-dressed leather shoes or gloves may absorb enough methyl bromide to cause severe injury. With care, however, the chemical may be used outdoors without a mask. Containers should never be opened indoors without a gas mask.

With the above exceptions, directions for controlling Texas leaf-cutting ants with methyl bromide are identical with those which follow for carbon disulfide.

Treatment with Carbon Disulfide

The advantage of carbon disulfide is its general availability. Its disadvantages are: high inflammability and explosiveness, making extreme caution necessary in transportation and use; the thoroughness of dosage required, making 2- to 3-man crews preferable for treating all but the smallest colonies; and the necessity for closing all discoverable burrows when applying the chemical. Properly applied, however, carbon disulfide works.

The equipment per man required for applying carbon disulfide consists of:

1 covered gallon container, with spout for accurate pouring.

1 5-foot length of $\frac{1}{4}$-inch hard rubber tubing, cut squarely at one end and at 45° at the other.

1 small funnel, inserted in the square-cut end of the tube, and marked to measure exactly 1.6 fluid ounces when the tube is pinched just below it.

1 laboratory spring clamp to close the tube below the funnel while measuring.

In addition, the U. S. Forest Service has found it expedient to provide a tall, white-painted durable post, serially numbered, with which to mark each colony treated (with conspicuous red flags for obscurely located colonies), and forms to record the serial number, size, and date or dates of treatment of each colony, the number of ant holes treated, the total amount of carbon disulfide used, and the total man-hours and truck miles required. The locations of all treated colonies are plotted on (usually 2-inch-to-the-mile) plantation maps. Only by means of such information can colonies be re-examined and retreated as necessary, treatments evaluated, and costs compared.

In applying carbon disulfide, crew members cross and recross the colony abreast, 10 feet apart, each man injecting the chemical in one nest opening in each 100 square feet, and closing with his heel all treated and untreated holes found in his 10-foot strip. In treating, the diagonally-cut end of the tube is eased into a hole, with a twisting motion, as far as it will go, preferably 2 feet. (The tube prevents absorption of carbon disulfide by surface soil.) Then the tube is clamped, 1.6 fluid ounces of carbon disulfide poured into the funnel, the clamp released, and the chemical allowed to drain into the nest. The chemical is not exploded after injection; the risk of injuring crew members and starting fires is too great, and U. S. Forest Service tests have shown that the chemical is more effective unexploded. Nevertheless, "firing" an occasional colony, by cautiously dropping a lighted match into a treated hole, is instructive because of the numerous overlooked holes, some at great distances, which the puffs of dust from the explosion reveal.

Carbon disulfide treatments cannot be made in cold weather because the chemical freezes around the nozzle of the can at temperatures somewhat above the freezing point of water.